THE

TRANSCONTINENTAL TRIANGULATION

AND THE

AMERICAN ARC OF THE PARALLEL.

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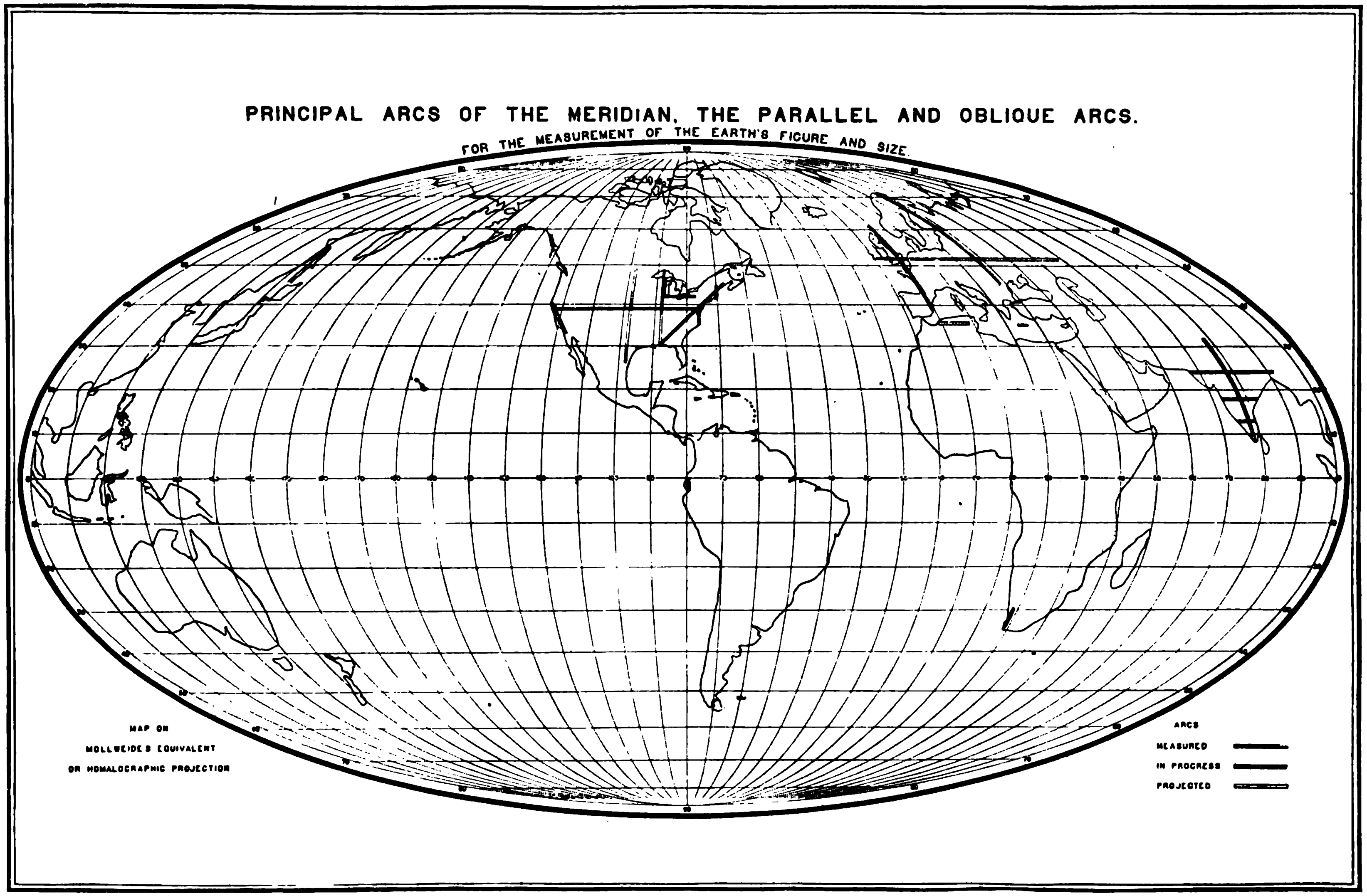
PRINCIPAL ARCS OF THE MERIDIAN, THE PARALLEL AND OBLIQUE ARCS.
FOR THE MEASUREMENT OF THE EARTH'S FIGURE AND SIZE.
MAP ON
MOLLWEIDE'S EQUIVALENT
OR HOMALOGRAPHIC PROJECTION
ARCS
MEASURED
IN PROGRESS
PROJECTED

TREASURY DEPARTMENT

U. S. COAST AND GEODETIC SURVEY

HENRY S. PRITCHETT,

SUPERINTENDENT.

GEODESY.

THE TRANSCONTINENTAL TRIANGULATION

AND THE

AMERICAN ARC OF THE PARALLEL.

By Assistant CHAS. A. SCHOTT, Chief of the Computing Division.

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THE TRANSCONTINENTAL TRIANGULATION AND THE AMERICAN ARC OF THE PARALLEL.

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FOREWORD.

The volume which is here presented to the scientific world contains the results of the most extensive piece of geodetic work attempted by any nation, a geodetic triangulation across the continent and the resulting arc of the parallel. This work has been conducted with the greatest care, and many improvements in the means of observation have marked its progress.

In presenting this complete record of a great undertaking, carried through by a bureau of the Treasury Department, the executive officers of the Department feel that it will prove a contribution to the science of the world worthy of the United States.

L. J. GAGE, *Secretary*.

TREASURY DEPARTMENT, *May, 1900*.

INTRODUCTION.

The completion of the measure of an arc of the parallel across the Continent of North America marks an epoch not only in the scientific history of the United States but in the world's geodesy as well. The results of the work, not only to geography but to geodesy, are most important and far-reaching. In the present volume are brought together not only the observations themselves and a discussion of the results, but also a description of the instruments and methods employed, and the improvements which have been brought about in the progress of the work. This progress has been coincident with that of the science of geodesy itself and, in a measure, the work has been a history of the science.

The transcontinental triangulation, which was designed to connect the triangulation lines already executed on the Atlantic and on the Pacific coasts, began under my predecessor, Professor Benjamin Peirce, the third Superintendent of the Survey, and the work has been prosecuted under the succeeding superintendents—Patterson, Hilgard, Thorn, Mendenhall, and Duffield.

Soon after the close of the Civil War it became evident that greater extension must be given to geodetic operations, in order to keep pace with the material development of our country. It was at that time that Superintendent Peirce asked Congress for $15 000 to begin a triangulation connecting the Atlantic and the Pacific coasts. He characterized the sum as "small in amount but of inestimable importance." So favorably was the project received in Congress that the necessary legislation was immediately enacted. The appropriations increased with each succeeding year until 1874, when $50 000 were allotted to the work.

During the next decade no specific amounts were set aside for this enterprise, but the work was carried on in connection with the general triangulation. Congress always authorized the expenditure of certain parts of the great items of appropriations for this particular purpose. The original idea was steadily kept in view, however, and in 1883 it again found formal expression in the sundry civil bill, by the appropriation of $30 000 for "transcontinental geodetic work." From this date to the completion of the general field work, regular annual appropriations were made. The total cost, from 1871 to

1897, exclusive of salaries of officers, was approximately $500 000, giving an average expenditure of about $20 000 yearly.

The cost per mile of progress was least in Maryland and Delaware, being $103, and greatest in California, where it was $463. The average expense of occupying one station was $598 in the former case and $9 031 in latter. The cost per square mile of territory, strangely enough, however, is greatest in a flat country, where short lines are necessary. The work in Indiana and Illinois cost $11 per square mile, where the average cost per point was $1 725, while that in Colorado cost about $2, where the cost of occupying each station was $6 131.

The immediate results are these: Sixteen States are given fundamental and permanent points on which all their subsequent surveys may be based. The longest arc of a parallel ever undertaken by any single government has been completed, and valuable material has been supplied for a more exact determination of the earth's size and shape. Precision in scientific work has been substantially increased during the period mentioned, and improvement in the field methods has been marked in the base measures, in the triangulation, and in the astronomical determinations. In fact, the progress of this work has kept pace with the progress of geodesy. Since the inception of the work, and growing out of its prosecution, great strides have been made in point of rapidity and accuracy. New methods have been introduced, consequent upon the gigantic scale of the operations. Astronomical results obtained at an altitude of 14 000 feet require special treatment on account of changed conditions in attractive and centrifugal forces. Horizontal angles, if the stations are extremely elevated, are sensibly different from what they would be at the level of the sea. The ordinary formula for spherical excess must be extended to meet the demands of the great triangles from Pikes Peak to the Sierra Nevada. The laws of refraction applicable at lower and equal elevations require modification when great inequalities exist in the heights of stations. The calculation of geographical positions enters a new phase when lines of sight 182 miles long are to be dealt with. The adjustment of the triangulation—that refined operation by means of which incongruous observations are made to blend harmoniously according to the mathematical theory of probabilities—assumes greater significance in a chain of 2 600 miles of continuous geometrical figures. The nature of the country traversed has developed new ideas in signals and tripods. The mounting of an instrument 152 feet above the ground, and the erection of an observing pole to a height of 275 feet, are features hitherto unknown in similar work. For the first time corrections have been introduced for the variations of latitude. The present volume, therefore, marks an epoch in the annals of the Coast and Geodetic Survey, and the completion of this great arc may be fittingly called one of the historic events in the progress of geodesy.

The method of treatment and the general results may be briefly stated as follows: Each base net was first adjusted separately. This gave, at intervals along the arc, certain lines whose lengths depend more directly upon measurement, and which were regarded as absolute. The triangulation intervening between any two adjacent figures thus established was treated by the method of least squares, so as to reconcile discrepancies between the fixed values and those resulting from the angular measurements

connecting them. The operation thus far gave a connected homogeneous system of figures throughout, and opened the way for the final computation of the individual geographical positions.

In order to determine standard data to which the entire arc should refer, a first preliminary reduction was made. This gave provisional values, which were afterwards corrected so that the average discrepancies between the computed positions and those determined by astronomical observations should be as small as possible.

Latitude was observed at 109 stations, azimuth at 73, and longitude at 37. The average local deflection, irrespective of sign, in the plane of the meridian, from 51 latitude comparisons, was about $2''.4$, and those in the prime vertical may be assumed, in general, to be of equal magnitude. After rejecting values which were clearly inadmissible on account of local configuration, the following corrections were made to the positions first adopted: In latitude $-0''.64$ and in longitude $+0''.37$. No change was required in the provisional azimuth.

The discrepancies between the positions deduced through triangulation and those determined astronomically may result from deflections of the plumb line or from the fact that the geometrical figures are developed on a spheroid whose dimensions are different from those of the actual earth. Moreover, the deflections may be local, as when caused by mountains, valleys, etc., or they may extend over great areas, where a change of density in the earth's crust is the underlying cause. As far as the present measures go, the curvature of the North American Continent along the 39th parallel seems to be intermediate between that of the Bessel and the Clarke spheroids. The accuracy of this deduction is evident from the fact that the probable error of the measured length of the total arc (4 224 kilometres) is only 26 metres, whereas the difference between the arc of a parallel in latitude 39° on the Clarke and on the Bessel spheroids is 615 metres.

It would be well-nigh impossible to give credit, in exact proportion to the service rendered, to all persons who have contributed to the accomplishment of this task. Preeminent on the list stands the name of C. A. Schott, who has been in active service in this Bureau for more than fifty years. He has had charge of all the computations, and the present report on the work stands substantially as it came from his hands. Assistance in the computations was given, principally, by M. H. Doolittle, E. H. Courtenay, D. L. Hazard, and J. F. Hayford. The volume was edited by E. D. Preston, assisted by A. F. Belitz.

Prominent among the officers who had charge of the field operations, and who are here arranged in the order of linear distance covered by their trigonometrical operations, appear the following: W. Eimbeck, F. D. Granger, A. T. Mosman, G. A. Fairfield, F. W. Perkins, G. Davidson, and O. H. Tittmann.

The following table is believed to contain the names in alphabetic order of all the officers in the regular service who took part in the operations. The year in which the observations were made and the character of the work executed by each officer are also shown:

TABULAR STATEMENT OF DISTRIBUTION OF WORK.

Observers.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.
A. L. Baldwin														
J. B. Baylor														
G. F. Bird									ΔH	ΔH		*H	H	H
H. W. Blair		Δ					Δ*	Δ*	Δ					
T. P. Borden									Δ		Δ			
C. O. Boutelle								Δ*						
J. B. Boutelle								Δ*					Δ	
C. H. Boyd	Δ	Δ	Δ											
B. A. Colonna							ΔH	*	H					
G. Davidson	*				Δ*H	Δ	Δ	Δ*	Δ*	Δ	Δ*		Δ	
G. W. Dean										*				
H. C. Denson														
E. F. Dickins					Δ		ΔH		*H		H			H
W. Eimbeck		*	Δ	Δ	Δ*H	Δ	ΔH	ΔH	Δ*H	Δ*H	Δ	Δ*	ΔH	Δ
G. A. Fairfield									Δ	Δ	Δ*	Δ*	Δ	Δ
W. B. Fairfield							Δ*	Δ	Δ	Δ		Δ*	Δ	Δ
R. L. Faris														
E. G. Fischer														
H. F. Flynn														
O. B. French														
J. J. Gilbert								H	*H					
F. D. Granger								Δ*	Δ*		Δ	Δ	Δ	Δ
J. F. Hayford														
W. C. Hodgkins														
E. B. Latham														
J. S. Lawson									*					
R. A. Marr								H	*H	*H	H	H	ΔH	H
J. E. McGrath									H		Δ	Δ		
F. Morse													H	H
A. T. Mosman			Δ	Δ*			Δ	Δ	Δ*	Δ		Δ*	Δ	Δ*
J. Nelson														
F. H. Parsons										*	*	*		*
F. W. Perkins									Δ			Δ*		
J. F. Pratt							ΔH	H	H		H*			
E. D. Preston														ΔH
H. P. Ritter														
C. Rockwell			Δ		Δ	Δ								
A. F. Rodgers							Δ	Δ	Δ					
L. A. Sengteller								Δ						
C. H. Sinclair										*	*			
E. Smith		*								*				*
H. L. Stidham														
J. A. Sullivan							Δ	Δ						
E. L. Taney														
C. Terry, jr									Δ			*		
O. H. Tittmann							Δ	Δ*H	ΔH	Δ*H				
J. H. Turner														
C. H. Van Orden	Δ	Δ	Δ											
D. B. Wainwright								ΔH						
J. B. Weir								H	ΔH	Δ	Δ			
P. A. Welker														
F. Westdahl														
I. Winston														
R. S. Woodward								Δ						
C. C. Yates														

NOTE.—Astronomical observations, whether for latitude, longitude, or azimuth, are indicated by *.
Triangulation, including reconnoissance, base lines, and horizontal angles, is denoted by Δ.

TABULAR STATEMENT OF DISTRIBUTION OF WORK—Continued.

Observers.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.
A. L. Baldwin											△	△	
J. B. Baylor				*									
G. F. Bird													
H. W. Blair													
T. P. Borden													
C O. Boutelle													
J. B. Boutelle					△					△H			
C. H. Boyd													
B. A. Colonna													
G. Davidson			*		△*		△	*					
G. W. Dean													
H. C. Denson												H	
E. F. Dickins						△H	△						
W. Eimbeck	△	△*	△*	△*H	△*H	△*H	△*H	△*H	△*H	H	△H		
G. A. Fairfield	△	△*		△*	△						△	△	
W. B. Fairfield	△	△		△*	△	△	△	△			△	△	
R. L. Faris							H	H	*H	*H		△	
E. G. Fischer						*	*		*				
H. F. Flynn												△H	
O. B. French					H	H	*H				*	*	
J. J. Gilbert					△*H						H		H
F. D. Granger	△	△	△*	△	△	△	△	△*	△H	△H	△*		
J. F. Hayford						△							
W. C. Hodgkins											△*		
E. B. Latham											△		
J. S. Lawson		△*											
R. A. Marr			*	*									
J. E. McGrath													
F. Morse		△			*						*		*H
A. T. Mosman	△	△*		△*	△	△		△					
J. Nelson								*	H	△*H	△	△	
F. H. Parsons			*										
F. W. Perkins		△				△	△		△H		△	△	
J. F. Pratt													
E. D. Preston													
H. P. Ritter												*	
C. Rockwell													
A. F. Rodgers													
L. A. Sengteller													
C. H. Sinclair	*	*	*	*		*		*				*	*
E. Smith	*					*	*						
H. L. Stidham								△*					
J. A. Sullivan													
E. L. Taney			H										
C. Terry, jr													
O. H. Tittmann						△							
J. H. Turner		*H	*								H		
C. H. Van Orden													
D. B. Wainwright													
J. B. Weir													
P. A. Welker		△*H		*H	*H	△*H	△*		H		△H	△	
F. Westdahl						△H	△H						
I. Winston					*H							H	
R. S. Woodward						△	△						
C. C. Yates											H		

Hypsometry, either by means of the spirit level or vertical angles, is shown by H.

The present addition to the literature of geodesy will ever remain of value, and will doubtless take its place among the epoch-making contributions to the subject.

Although the influence of this arc in the determination of the earth's figure is one of its cardinal virtues, the work will exercise its full power and accomplish its complete purpose only when combined with an arc now being measured on the ninety-eighth meridian, and which will ultimately traverse Mexico, the United States, and the British possessions. When this great counterpart of the triangulation along the thirty-ninth parallel shall have been measured, and the results of the two have been combined, we shall be in possession of sufficient data to define a surface of the country which, in the present state of exact measurements, may be considered a finality.

HENRY S. PRITCHETT,
Superintendent.

UNITED STATES COAST AND GEODETIC SURVEY,
Superintendent's Office, April, 1900.

PRELIMINARY STATEMENT.

I. LOCATION, SCOPE, AND PURPOSE OF THE TRANSCONTINENTAL TRIANGULATION, WITH HISTORICAL NOTES AS TO ITS INCEPTION AND PROGRESS.

This transcontinental triangulation and measure of an arc of the parallel extends from Cape May, New Jersey, on the Atlantic coast, in longitude 74° 55'·8, to Point Arena, California, on the Pacific coast, in longitude 123° 41'·8. The intervening distance is about 4 225 kilometres, or 2 625 statute miles, corresponding to 48° 46'·0 of longitude.

Its terminal points are near Cape May and Point Arena light-houses, which are in latitudes 38° 55'·9 and 38° 57'·3, respectively.

The desirability and necessity of uniting the main triangulations along the eastern and western coasts of the United States must have impressed itself upon the minds of those engaged in the work. It was recognized that such a connecting bond was demanded in order that these separate parts might be made to depend upon the same geodetic and astronomic data. By this means only could the unity and consistency of the work of the Survey be secured; besides, it was apparent that any proposed surveys of States lying in the path of the connection or adjacent thereto could at once be based upon the same standard data, thus securing uniformity and accuracy for the whole work. An operation of this character could not well be undertaken by separate State action, since it would involve too many contingencies respecting uniformity of treatment and of timely cooperation. Its execution was therefore properly intrusted to the Coast and Geodetic Survey as one of its functions.

Besides its immediate practical benefit of providing a tier of interior States with a nucleus of systematic triangulation at once available for the extension of surveys over adjacent areas and furnishing geographic positions within these extended limits, the measure has a much higher value from a scientific standpoint. It is a considerable contribution toward those data of which geodesy must avail itself for the more exact determination of the earth's shape and size. For this and kindred measures an additional stimulus was given in 1889, when the United States became a member of the International Geodetic Association for the measurement of arcs and for the special duty of investigating the geoid or deformed physical surface of the earth as contrasted with that of a mathematically defined figure.

The initial step toward the accomplishment of the measure was taken by Superintendent Benjamin Peirce. Under date of February 7, 1871, he asks, in his annual report to Congress for the year 1870 (page 7), for a *specific appropriation* for this object. On page 4 of that report we find, "A new item is proposed in the estimates, small in amount, but of inestimable importance to the scientific accomplishment of the Survey." Speaking of the geodetic connection between the Atlantic and Pacific coasts,

he remarks: "It will give to the National Government and incidentally to the several States the best possible basis for all accurate surveys which may hereafter be required." Ground was broken in July, 1871, in the vicinity of St. Louis, Missouri, by laying out a triangulation extending to the eastward and westward of that city and providing for a base line and astronomic measures. It was also evident that part of the operations already carried out by the Survey in central California during nearly twenty years could be utilized or incorporated into the arc measure; likewise at its eastern end it was expected that some part of the very much older triangulation with its astronomic measures would be included.

Since the year 1871 the work has been continued under the several superintendents. Although the annual accretions were small, owing to the meager appropriations allotted, it can be said that at the close of the year 1896 the measure of horizontal angles of the triangulation was completed. The last of the base lines was measured in 1897, but the determination of heights of the Rocky Mountain stations yet demanded certain measures of zenith distances and spirit levels, which were supplied in 1898. In the same year the last of the astronomic longitude determinations was made. The reduction of the observations and the preliminary computation of positions were kept abreast with the field work, but some unavoidable delay in the final adjustment and preparation for the press occurred in consequence of the late supply of the height measures required for reducing two of the principal base lines to the sea level.

The accompanying map A (in pocket), on a scale of $\frac{1}{7\,000\,000}$, has been specially designed to give at a glance a general view of the location and comparative extent of the triangulation connecting our east and west coasts. It exhibits by contrast of color the base nets and the intervening chains of triangulation, and by their variation in width it indicates the dependence of the size of the triangles on the hypsometric features of the country. On map B (in pocket) is shown, by means of the simple conventional signs adopted on the Survey, the number and distribution of the astronomic stations whether for longitude, latitude, or azimuth.

In connection with the measure of this arc of the parallel it may not be out of place here to direct attention to the report of the Geodetic Conference of January and February, 1894, convened by Superintendent T. C. Mendenhall. (Appendix No. 9, Coast and Geodetic Survey Report for 1893, Part II, specially pp. 360–363.) Reference will be found therein to other arcs measured either by the United States Lake Survey or by the Coast and Geodetic Survey. The measures of the great meridional arc in longitude 98° west of Greenwich were commenced in 1897.* This proposed arc may be considered as complementary to the arc of the parallel, one giving a measure of the curvature in a north and south direction, the other in an east and west direction, thus affording within the limits of the country the means for determining an osculating spheroid closely approximating to the curvature of the earth's surface. The first half of the current year (1898) also saw the completion of the measures, geodetic and astronomic, of the great oblique arc stretching from Calais, Maine, at the Canadian boundary to west base, Dauphin Island, Alabama, on the Gulf of Mexico, thence to New Orleans, Louisiana, a length of 23° 31′, or 2 612 kilometres or 1 623 statute miles.

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*Reconnaisance was made in the preceding year.

2. SUBDIVISIONS OF THE CHAIN OF TRIANGULATION AND THEIR DISTINGUISHING CHARACTERISTICS.

The contrast in the physical features along the arc of the thirty-ninth parallel is so well pronounced as conveniently to mark out for general description three subdivisions, which moreover demand, in part at least, different mathematical treatment in the reduction of the observations. These subdivisions are designated the western, the central, and the eastern sections.

The *western* section is characterized by the great altitudes of its stations and the unusually large size of its triangles, many of the sides being over 160 kilometres, or 100 statute miles in length. The triangulation crosses the Coast Range, the Sierra Nevada, the Wasatch Range, and the main ridge of the Rocky Mountains, with many of its stations more than 3 kilometres, or nearly 2 statute miles, above the level of the ocean. The total linear development between Point Arena on the coast and Big Springs off the eastern flank of Pikes Peak, Colorado (as projected on the parallel of 39°) is nearly 1 685 kilometres, or 1 047 statute miles.

The *central* section, which extends from Big Springs, Colorado, eastward as far as St. Louis, Missouri, over a distance of about 1 217 kilometres, or 756 statute miles (measured on the parallel of 39°), partakes of the very opposite character from its neighbor with respect to width of development or average length of sides. The latter is but 27·3 kilometres, or 17·0 statute miles, and is therefore a minimum value. This feature was imposed upon it by the general flatness of the great plain which lies between the eastern slope of the Rocky Mountains and the Mississippi River, descending very gradually from about 1 800 metres (5 900 feet nearly) to about 135 metres, or 443 feet, above the sea level. As a rule the theodolite was mounted on tripods or scaffolds in order to overcome the earth's curvature and keep the line of sight sufficiently elevated above the ground.

The third or *eastern* section differs from the others by its small but diversified hypsometric features being composed of plains, low hills, and mountain ranges. Where the triangulation traverses the Alleghenies altitudes exceeding 1 300 metres, or 4 265 feet, are met. The section crosses the Chesapeake and Delaware bays, terminating at the capes of the latter. Its total (referred) length is about 1 323 kilometres, or 822 statute miles.

The triangulation across the country possesses great internal rigidity by reason of its composition throughout. Either quadrilaterals or central figures such as polygons formed by combination of triangles compose the scheme, while its length is supported by 10 base lines suitably distributed.

3. GENERAL STATEMENT IN REGARD TO THE ASTRONOMIC MEASURES.

Respecting the astronomic measures there are 109 stations directly connected with the triangulation at which the latitudes were determined almost *exclusively by Talcott's* method. These observations fall between the years 1846 and 1898. Eight latitudes depend on other than Coast and Geodetic Survey authority. Astronomical azimuths were obtained at 73 of the trigonometric stations between the years 1849 and 1897. A variety of methods, suitable to the circumstances at the time, were employed in this

work. On account of local deflections of the vertical, which are present to a greater or less amount at all stations, the value of an arc of the parallel depends, *cæteris paribus*, largely upon the number of subdivisions or component arcs which together make up its whole longitudinal amplitude. There are 37 astronomic longitude stations not very unevenly distributed over the arc, though rather crowded in some places. They were determined by means of the electric telegraph, and are either part of or depend directly upon the general telegraphic longitude system of the United States. An account of this system is contained in the annual report of the Survey for 1897, Appendix No. 2.* The longitudes were determined between the years 1869 and 1898. The stations, in consequence of the impracticability of establishing wire connections, are not, as a rule, also trigonometric stations in the main series of triangles, but all are geodetically connected with the nearest triangulation station.

*An abstract of this paper appeared in No. 412 (September 14, 1897) of Gould's Astronomic Journal.

PART I.

UNIT OF LENGTH, BASE LINES, AND BASE NETS.

CONTENTS OF PART I.

I. UNIT OF LENGTH, BASE LINES, AND BASE NETS.

(A.) INTRODUCTION.

In this first part of the exposition of the measurement of the arc of the parallel, stretching centrally across the country, will be presented a discussion of the unit of length upon which its whole extent is developed. This is followed by an individual account of each base line with its resulting length and probable error, and the adjustment of its net of triangles referring the base to a principal side of the triangulation. The methods of local and of figure adjustment of angles and sides are here explained.

(B.) THE UNIT OF LENGTH.

1. HISTORY OF THE COMMITTEE METRE OF 1799.

The unit of length of the transcontinental triangulation is the metre. Its material representative as used on the Survey from the beginning up to the year 1890 was an iron bar standardized at Paris in 1799 by the Committee on Weights and Measures. It was brought to America in 1805* by F. R. Hassler (afterwards first Superintendent of the Coast Survey) and presented by him to the American Philosophical Society of Philadelphia, and later placed by the society at the disposal of the Coast Survey. Mr. Hassler received it from J. G. Tralles, deputy to the commission from the Helvetic Republic. It was made by Lenoir at Paris and is one of 16 metres, of which twelve were distributed to the foreign commissioners, and bears among other distinguishing marks that of three dots ⁘. It is an end metre with cross section 9 by 27·5 millimetres. For an account of its construction, the apparatus employed, and method adopted for cutting the several metre bars to the desired length, the publications† given below will be found to contain nearly all that may be of present interest. Its use was discontinued after the receipt in November, 1889, by the Government of the United States from the International Bureau of Weights and Measures at Paris of three representative platinum-iridium bars of the International or Prototype Metre. Hence part of the triangulation depends for its length on the Committee Metre, or C.M., part on the International Prototype Metre and part through adjustment on both. Under these circumstances it became imperative to carefully compare these standards, which were supposed to be equal, and, if different, to correct the length of

* Pub. Doc. No. 299, H. of Reps., 22d Congress, 1st session, Washington, 1832, p. 6.

† Transactions American Philosophical Society, Philadelphia, Vol. II, new series, No. XII. "Papers on various subjects connected with the Survey of the Coast of the United States," by F. R. Hassler, March 3, 1820 (p. 253 in particular); United States Coast Survey Report for the year 1867, Appendix No. 7 pp. 134–137; Recherches historiques sur les Étalons de Poids et Mesures de l'observatoire et les appareils qui ont servi à les construire. Par M. C. Wolf. Paris, 1882.

the older base lines depending on the Committee Metre of 1799, in order to express their length and that of the whole triangulation in terms of the International Prototype Metre.

In attempting to determine their relative length, two difficulties presented themselves—one due to the demand of modern science for greater accuracy and better definition than was the case a century ago, and the other due to a slight yet perceptible deterioration of the end surfaces of the iron metre by oxidation and by wear. It was hoped that the length of this metre could become known with no greater probable error than one micron. An error of one-millionth part of the length would produce one of 4·2 metres in the width of the country in latitude 39° and would be a negligible quantity in comparison with the inevitable errors introduced through the triangulation.

2. THE COEFFICIENT OF EXPANSION OF THE IRON COMMITTEE METRE, OR "C.M.".

There is no information of a special determination of the coefficient of expansion of this metre by the committee of 1799. The average value for the several metres was $11·56 \times 10^{-6}$. A direct determination made at Newark by F. R. Hassler in 1817* gave him 0·000 006 963 5 for Fahrenheit's scale or the value for the centigrade scale of $12·534 \times 10^{-6}$. This rather large value was supposed due to the method employed, which would now be characterized as crude. The result was not adopted on the Survey, but the committee's value was employed instead up to about the year 1881, when an elaborate series of observations was made by Assistants C. A. Schott and H. W. Blair at the Survey office in connection with the work of standardizing a new 5-metre bar. During these observations the C.M. and 5 other metres were immersed in a bath of glycerin, the temperature of which, when steady, was found by means of standard thermometers. The ends of the bars protruded slightly beyond rubber diaphragms placed tightly in holes piercing the ends of the trough, which was then brought between two Bessel-Repsold screw spirit-level comparators. The range of the temperature of the glycerin and immersed bars was between 4° and 38°C. (39° and 100° F.). The results from the several series were as follows:

		Expansion for 1° F.	
1880, Dec.	23–24	6·576 μ	Mean 6·550 μ ± 14 equal to $11·790 \times 10^{-6}$ for C. scale ± 25
	27–29	6·603	
1881, Jan.	3–8	6·613	
	2–3	6·508	
	4–5	6·495	
	7–8	6·579	
	16–17	6·474	

Particulars of these operations will be found in Coast and Geodetic Survey Report for 1882, Appendix No. 7 (p. 124 in particular).

In 1888 and 1889, Assistant O. H. Tittmann made a series of comparisons† for

* Trans. Amer. Phil. Society, Philadelphia, Vol. I, new series, No. XVI. An account of pyrometric experiments made at Newark, New Jersey, April, 1817. By F. R. Hassler.

† Coast and Geodetic Survey Report for 1889, Appendix No. 6: "The relation between the metric standards of length of the United States Coast and Geodetic Survey and the United States Lake Survey." By C. A. Schott and O. H. Tittmann, Assistants. pp. 179–197.

relative lengths of the United States Lake Survey Repsold Metre R.M. and the committee metre. These gave in connection with the coefficient of expansion of the R.M. (as finally given by Dr. Foerster, viz: $10{\cdot}654 \times 10^{-6}$, by Lake Survey observations, $10{\cdot}615 \times 10^{-6}$, and by International Bureau of W. and M., $10{\cdot}563 \times 10^{-6}$), ± 11 the resulting values, in combination with other measures, for coefficient of R.M. $10{\cdot}606 \times 10^{-6}$, and for C.M. $11{\cdot}795 \times 10^{-6}$ (± 25), a value practically identical with the one found in 1880–81. A further confirmation of this value was had through the direct comparisons of the C.M. with one of the national prototype metres. Mr. L. A. Fischer obtained between July, 1894, and May, 1895, a large number of micrometric differences between the length of the C.M. and of the N.P.M. 21. These observations were made in a vault at the office, in which the temperature was varied 21½° C. The optical method was employed, varied by the use of 2 prongs 3 millimeters distant on each side of the axis, the bars and thermometers being under glass cover on the comparing carriage, provided with the necessary adjustments. The details of the process being explained farther on, it suffices to state here the resulting differential expansion, viz: $y = +3{\cdot}123\,\mu$. The coefficient of expansion of the N.P.M. 21 was determined at Breteuil, viz: $+8{\cdot}665 \times 10^{-6}$, whence the coefficient for the C.M. $= 11{\cdot}788 \times 10^{-6}$.

Recapitulation of values for coefficient of expansion of the C.M.:

1799	$11{\cdot}56 \times 10^{-6}$
1880–81	$11{\cdot}790$
1888–89	$11{\cdot}795$
1894–95	$11{\cdot}788$
Mean adopted	$11{\cdot}791 \times 10^{-6}$ ± 2

3. THE LENGTH OF THE IRON COMMITTEE METRE, OR "C.M."

From the particulars given by F. R. Hassler* respecting the construction of the original metres it would appear that the aim of the committee was to secure an accuracy in their length which should be trustworthy to within about half a micron. It is further stated that the difference in length of the temporarily selected standard and metre :· or the C.M. was two ten-millionths part of a toise, the latter being the shorter. If this was correctly understood we would have C.M. $= 1m - 0{\cdot}4\mu$.

In 1867 the C.M. was taken to Paris for direct comparison with the standards preserved there. A full account of the work done is contained in Coast Survey Report for 1867.† During these comparisons the respective metres were immersed in melting ice. The measures were made by means of the Silbermann comparator with the aid of two abutting pieces. The resulting length of the C.M. arrived at makes it too long by $3{\cdot}36\mu$, but the first and third series of comparisons show rather a wide difference, and considering that so few series of comparisons were made we may regard the result as a weak one. The actual operation occupied but a few hours of August 24.

* Pub. Doc. No. 299, pp. 75 and 77.

† Report for 1867, Appendix No. 7, pp. 134–137.

A more satisfactory although indirect comparison was obtained in 1889* through the medium of what is known as the Repsold steel metre of the United States Lake Survey, R.M., the length of which had been determined at Breteuil, near Paris, in January, 1883. The C.M. being an end and the R.M. a line metre, Assistant Tittmann employed the optical or reflection method for comparing the two bars, which was effected at Washington in a cold-storage room and other localities between September, 1888, and March, 1889. The R.M. is otherwise of importance through the fact that the length of the Olney base line in Illinois is expressed in terms of it, for which see Report upon the Primary Triangulation of the United States Lake Survey, by Lieut. Col. C. B. Comstock.† In a supplement by General Comstock, dated February 28, 1885, the length of R.M. is given provisionally, but very closely, as $1m + 97{\cdot}81\mu$ at the temperature of melting ice, and for any temperature t (centigrade) there is to be added $\overset{\mu}{10{\cdot}615}t$; but in the 1889 report, p. 186, the preferable value, $\underset{\pm\ 25}{10{\cdot}606} \times 10^{-6}$, is deduced for the coefficient of expansion. From these Washington observations we derive

$$\text{R.M.} - \text{C.M.} = \underset{\pm{\cdot}49}{84{\cdot}28\mu} - \underset{\pm\ 425}{\overset{\mu}{1{\cdot}1925}}\,(t - 11^{\circ}{\cdot}66)$$

$$\text{and C.M.} = 1m - 0{\cdot}38\mu \pm 0{\cdot}70\mu$$

Between July, 1894, and May, 1895, an extensive series of comparisons before alluded to was made at Washington by Mr. L. A. Fischer, of the Weights and Measures Office, between the C.M. and one of the new National Prototype Metres known as N.P.M. 21, received here in July, 1890. The latter is a platinum-iridium line metre of length $1m + \underset{\pm\ {\cdot}15}{2{\cdot}5\mu} + \overset{\mu}{8{\cdot}665}t + \overset{\mu}{0{\cdot}001\ 00}t^2$, as standardized at Paris. The comparisons‡ were made in the office comparing vault by means of micrometer microscopes clamped to a steel beam as support. The two standards were placed in a glass-covered box or carriage and were supported at two points 54 centimetres apart, with Tonnelot thermometers placed on their upper surfaces in contact with them. The carriage rested on iron rollers and was provided with all necessary adjusting devices. For defining the ends of the C.M. the optical method was employed, but as the end surfaces are less perfect in the axis of the bar than at a short distance from it, two points 6 millimetres apart were placed symmetrically to the axis to admit of their direct and reflected images. Illumination was secured by means of right-angled prisms placed about 1 centimetre below the bar, the light from incandescent lamps being thus thrown upward. The defining lines of the N.P.M. were made visible by throwing the light upon them through 45° prisms placed between the two lenses of the objectives of the microscopes. An observation consisted of the following operations: 1. Reading of thermometers. 2. Pointings on C.M. 3. Pointings on N.P.M. 4. Pointings on C.M. 5. Reading of thermometers—the whole occupying about 12 minutes, during which time the thermometers

* U. S. Coast and Geodetic Survey Report for 1889, Appendix No. 6. "The relations between the metric standards of length of the U. S. Coast and Geodetic Survey and the U. S. Lake Survey, by C. A. Schott and O. H. Tittmann, pp. 179-197.

† Professional Papers Corps of Engineers, U. S. A., No. 24, Washington, 1882.

‡ Not yet published.

rose about $0^{\circ}\cdot1$ C. Following a regular scheme, the bars at different times were placed in different positions with respect to the observer and microscopes. The temperature of the vault ranged between $2^{\circ}\cdot7$ and $24^{\circ}\cdot2$ C. The 96 individual observations when condensed into 4 groups gave the following conditional equations:

$$
\begin{aligned}
& \qquad\qquad\quad \mu \\
x + 22\cdot340y &= 69\cdot71 \\
x + 7\cdot442y &= 23\cdot71 \\
x + 3\cdot747y &= 11\cdot68 \\
x + 10\cdot550y &= 34\cdot07
\end{aligned}
$$

whence the normal equations

$$
\begin{aligned}
4\cdot000\,x + 44\cdot079y &= +139\cdot17 \\
44\cdot079\,x + 678\cdot908y &= +2136\cdot97
\end{aligned}
$$

hence $x = +0\cdot38\mu$, or the difference C.M. — N.P.M. at 0° C and $y = +3\cdot123\mu$ or the differential expansion per degree centigrade. The result is C.M. $= 1m + 2\cdot88\mu$ at the temperature of melting ice.

The preceding 4 determinations not being as accordant as desirable, further observations were undertaken at the office by Mr. Fischer and also by Assistants G. R. Putnam and A. Braid between January 17 and March 3, 1896. These operations differed from the preceding one by the substitution of the contact piece method for the reflection method; otherwise the conditions were the same. Since no publication has been made, a somewhat more full description will be given here, taking the same from the preface as given by Mr. Fischer.* Two platinum abutting pieces were made, consisting of thin disks about $6\cdot3$ millimetres in diameter with their central areas hollowed out in order to produce a ring contact about the axis of the C.M. On the side opposite the contact surface there was a ledge, level with the center of the disk, upon the horizontal surface of which were drawn two lines parallel to the axis of the bar and a fine perpendicular line about $0\cdot8$ millimetre from the plane of the disk for observation; when under comparison, the disks were held by light springs supported by a collar clamped about the ends of the C.M. After observation had been made in one position the end pieces were taken off and their abutting surfaces placed in contact and the distance of their fiducial lines measured. After this the end pieces were again put on the metre, its ends having been reversed. The values of micrometers Nos. 5 and 6 were found by measuring the millimetre spaces on N.P.M. 21, which were at its A end $1008\cdot6\mu$ and at its B end $997\cdot0\mu$ apart. The value of 1 turn of micrometer No. 5 is $74\cdot697\mu$ and of No. 6, $75\cdot982\mu$ (January 18 and 24); differential expansion of the two metre bars $3\cdot126\mu$ for 1° C.; range of temperature during the comparisons between $0^{\circ}\cdot72$ and $5^{\circ}\cdot62$ C.; corrections were applied to thermometers Tonnelot Nos. 4333 and 4334 for position of zero point, graduation and reduction to hydrogen scale; distance of lines on disks when in contact, $1627\cdot32\mu$; the outer lines of the N.P.M. having been observed, we have the distances 1 to 2 $= 499\cdot7\mu$, and 5 to 6 $= 493\cdot9\mu$.

* After the above had been written, a paper read before the Philosophical Society of Washington on May 28, 1898, by Mr. L. A. Fischer, was received. It is entitled "On the comparison of line and end standards" (see Bulletin Vol. XIII, p. 241, and fol.). The result (that of 1896) is the latest on record, and the author thinks it is at least as trustworthy as that derived from the optical or Fizeau method.

Recapitulation of mean values for each observer.

	Fischer.	Putnam.	Braid.
No. of series	17	9	12
Corrected temperature of C.M.	4°·210	4°·218	2°·656
Corrected temperature of N.P.M.	4 ·204	4 ·237	2 ·672
Observed micrometric difference of length	643 ·071μ	642 ·692μ	638 ·240μ
C.M. at 0° C. shorter than 1 m.	1 ·36	1 ·55	1 ·14

Mean length = $1m - 1{\cdot}3\mu \pm 0{\cdot}1\mu$.

Summary of results for length of C. M. in terms of the P. M.

Year.	Length.	
1799	$1m - 0{\cdot}4\mu$	
1867	$+3{\cdot}4$	
1889	$-0{\cdot}4$	Indiscriminate mean $1m + 0{\cdot}8\mu \pm 0{\cdot}7\mu$.
1894–95	$+2{\cdot}9$	
1896	$-1{\cdot}3$	

Scanning these results, it would appear that they represent rather irregularities of the surfaces about the axis than measures of the true length of the bar. If so, equal weight would attach to them. On the other hand, the value of 1867 rests upon a very meager number of observations, on which account less weight (one-half) might be assigned to it, whereas somewhat greater weight (two) might be given to the 1896 comparisons by reason of the great care bestowed upon the measures and in particular on the determination of the temperature of the bars. Applying these weights we get the length of the C.M. at 0° C. = $1m + 0{\cdot}2\mu \pm 0{\cdot}6\mu$. The probable error of the determination being much larger than the difference in length of the bar from one metre, we may take the C.M. to be equal to the prototype standard without any serious error and with a probable uncertainty of about three-quarters of a micron.

(C.) THE LOCAL OR STATION ADJUSTMENT OF HORIZONTAL ANGLE AND DIRECTION OBSERVATIONS.

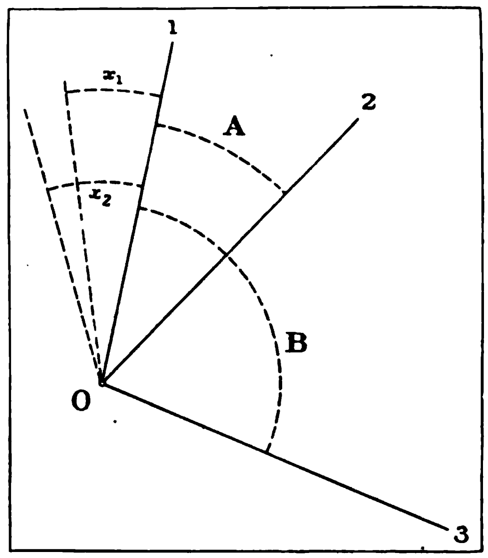
The abstract of resulting directions from theodolite measures and the adjustment of the triangles composing the base nets, together with the computation of the probable errors of resulting sides, demand further exposition of the methods employed.

The great majority of the angular measures were made in series with different positions of the circle. These are called direction observations. At three only of the base nets do we find some angular measures by means of repeating theodolites. In the latter case the weights introduced will depend on the number of repetitions. The least square adjustment to satisfy the conditions among the measured angles generally proceeds by the method employing correlate equations.* By addition, the adjusted angles are referred to an initial direction and the results given in the abstracts are in the order in which azimuths are counted (i. e., clockwise). For some of the base nets

*The process is so well understood as to need no further remarks; reference may be made to T. W. Wrights' Treatise on the Adjustment of Observations, New York, 1884, Chapters IV, V, and Part of VI.

the station abstracts include a column giving rough values of probable errors of the respective directions, which were not in all cases computed, and had heretofore been made use of only in one instance—that of the Yolo Base net, as will be explained further on.

No.



I. GENERAL DISCUSSION FOR LOCAL ADJUSTMENT OF DIRECTION OBSERVATIONS.*

"Let O be the station occupied and 1, 2, 3, ... the stations sighted at in order of azimuth. Let some one direction, as O1, be selected as the zero direction, and let A, B, ... denote the most probable values of the *angles* which the directions of the different signals make with this direction."

In the first series of readings let X_1 denote the most probable value of the angle between the direction defined by the zero of the limb of the instrument and the direction O1. Let M_1', M_1'', M_1''', ... denote the readings of the limb on signals 1, 2, 3, ...

Then for the first series of readings we may write the following observation equations, one for each reading: †

$$\left.\begin{array}{c} X_1 \quad\;\; - M_1' \;\;= v_1' \\ X_1 + A - M_1'' = v_1'' \\ X_1 + B - M_1''' = v_1''' \\ \cdots \quad \cdots \quad \cdots \quad \cdots \\ \text{Similarly for the second series of readings we may write} \\ X_2 \quad\;\; - M_2' \;\;= v_2' \\ X_2 + A - M_2'' = v_2'' \\ X_2 + B - M_2''' = v_2''' \\ \cdots \quad \cdots \quad \cdots \quad \cdots \\ \text{and so on, for all the series.} \end{array}\right\} \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

The number of observation equations is equal to the number of readings (signal sightings) at the station, and is designated by n.

The subscript in each case indicates the number of the series, while the superscript indicates the signal sighted.

The unknowns are X_1, X_2, X_3, ..., one for each series, and A, B, C, ..., one for each direction except the initial direction. The total number of unknowns is $s + d - 1$, in which s = number of series and d = number of directions (or signals

* See Wright's Treatise on Adjustment of Observations, New York, 1884, pp. 315–320.

† The essential difference between *direction* observations and *angle* observations, from the point of view of least squares, is that with *direction* observations there is an observation equation for each *reading*, while with *angle* observations there is an observation equation for each *angle* measured.

sighted upon). Of these unknowns it is important to note that the X's are *not required;* they are unknowns introduced by the method of observation. A, B, C, ... are the required unknowns, and the solution is to be put in such form as to give only these unknowns and not the X's.

To insure that only small numerical terms shall occur in the solution, let

$$\begin{array}{ll} X_1 = M_1' + x_1 & A = A' + (A) \\ X_2 = M_2' + x_2 & B = B' + (B) \\ \cdots\ \cdots\ \cdots & \cdots\ \cdots\ \cdots \end{array}$$

where M_1', M_2', ..., the readings upon the initial direction, are taken as convenient approximate values of X_1, X_2, ...; and A', B', ... are approximate values of A, B, ...

Then the observation equations shown in (1) may be written

$$\left.\begin{array}{ll} x_1 \qquad\qquad\qquad = v_1' & x_2 \qquad\qquad\qquad = v_2' \\ x_1 + (A) - m_1'' = v_1'' & x_2 + (A) - m_2'' = v_2'' \\ x_1 + (B) - m_1''' = v_1''' & x_2 + (B) - m_2''' = v_2''' \\ \cdots\ \cdots\ \cdots & \cdots\ \cdots\ \cdots \end{array}\right\} \cdots\cdots\cdots (2)$$

$$\begin{array}{lll} \text{in which} & m_1'' = M_1'' - M_1' - A' & m_2'' = M_2'' - M_2' - A' \\ & m_1''' = M_1''' - M_1' - B' & m_2''' = M_2''' - M_2' - B' \\ & \cdots\ \cdots\ \cdots & \cdots\ \cdots\ \cdots \end{array}$$

The absolute term in the first equation of each group is necessarily zero ($= M_1' - M_1'$, $M_2' - M_2'$, ...).

Let the weights of the various observations be p_1', p_1'', ..., p_2', p_2'', ..., the subscripts and superscripts having the same meanings as before.

Then the normal equations formed from the observation equations shown in (2) are

$$\left.\begin{array}{l} [p_1]x_1 \qquad\qquad + p_1''(A) + p_1'''(B) + \cdots\cdots - [p_1 m_1] = 0 \\ \qquad [p_2]x_2 \qquad + p_2''(A) + p_2'''(B) + \cdots\cdots - [p_2 m_2] = 0 \\ \cdots\ \cdots\ \cdots\ \cdots\ \cdots \end{array}\right\} \cdots\cdots * (3)$$

$$\left.\begin{array}{l} p_1'' x_1 + p_2'' x_2 + \cdots + [p''](A) \qquad\qquad - [p'' m''] = 0 \\ p_1''' x_1 + p_2''' x_2 + \cdots \qquad + [p'''](B) \qquad - [p''' m'''] = 0 \\ \cdots\ \cdots\ \cdots\ \cdots\ \cdots \end{array}\right\} \cdots\cdots (4)$$

Since the unknowns x_1, x_2, x_3...... are not required, we may eliminate them from the full set of normal equations shown in (3) and (4) by substituting their values as derived from the separate equations of (3) in each of the equations of (4). The result will be a set of equations, shown in symbolic form in (5), equal in number to the required corrections (A), (B) ...... and from which (A), (B)...... may be derived directly without resorting to the long set of equations shown in (3) and (4).

$$\left.\begin{array}{l} [aa](A) + [ab](B) + [ac](C) \cdots\cdots - [al] = 0 \\ [ab](A) + [bb](B) + [bc](C) \cdots\cdots - [bl] = 0 \\ [ac](A) + [bc](B) + [cc](C) \cdots\cdots - [cl] = 0 \\ \cdots\ \cdots\ \cdots\ \cdots \end{array}\right\} \cdots\cdots (5)$$

* The square bracket [ ] is used as usual to indicate the summation of similar terms.

in which

$$\left.\begin{aligned}
[aa] &= [p''] - \frac{(p_1'')^2}{[p_1]} - \frac{(p_2'')^2}{[p_2]} - \cdots\cdots \\
[bb] &= [p'''] - \frac{(p_1''')^2}{[p_1]} - \frac{(p_2''')^2}{[p_2]} - \cdots\cdots \\
[ab] &= -\frac{(p_1'')(p_1''')}{[p_1]} - \frac{(p_2'')(p_2''')}{[p_2]} - \cdots\cdots \\
[ac] &= -\frac{(p_1'')(p_1'''')}{[p_1]} - \frac{(p_2'')(p_2'''')}{[p_2]} - \cdots\cdots \\
[al] &= [p''m''] - \frac{p_1''[p_1m_1]}{[p_1]} - \frac{p_2''[p_2m_2]}{[p_2]} - \cdots\cdots \\
[bl] &= [p'''m'''] - \frac{p_1'''[p_1m_1]}{[p_1]} - \frac{p_2'''[p_2m_2]}{[p_2]} - \cdots\cdots
\end{aligned}\right\} \cdots\cdots (6)$$

The symbols, p, representing the relative weights have been used in the preceding equations merely to keep the equations in a convenient general form. In actually making the local adjustment all observations are given equal weight, and the various p's are all called unity. It is known that observations upon some signals (which appear distinct and steady) are more accurate than others (upon signals which appear unsteady or indistinct). But the difficulty of properly estimating the relative weights, and the extra labor of making the computation after they have been introduced, make it advisable to assign equal weights to all observations. The actual computation of the coefficients and absolute terms in (5) is therefore much less laborious than would appear from the forms shown in (6). This computation is also considerably shortened by grouping together all series in which every one of the (d) signals were observed, all series in which ($d-1$) signals were observed, and so on. Within these groups subgroups are also arranged comprising series upon the same combination of signals.

Under equations (5) the following additional check equation $[oo]O + [oa]\,(A) + [ob]\,(B) + [oc]\,C \cdots\cdots - [ol] = 0 \cdots\cdots (7)$ may be written.

This equation is to be used simply to furnish checks. In form it bears the same relation to the initial direction O1 that the first of (5) bears to the direction O2. Thus

$$[oo] = (p') - \frac{(p_1')^2}{[p_1]} - \frac{(p_2')^2}{[p_2]} - \cdots\cdots$$

$$[oa] = -\frac{(p_1')(p_1'')}{[p_1]} - \frac{(p_2')(p_2'')}{[p_2]} - \cdots\cdots$$

$$[ol] = -\frac{p_1'[p_1m_1]}{[p_1]} - \frac{p_2'[p_2m_2]}{[p_2]} - \cdots\cdots$$

In equations (5), as thus augmented by the addition of equation (7), the sum of the coefficients in *each* vertical column is zero. For example, in the column containing (A) $[aa] + [ab] + [ac] \cdots\cdots + [oa] = 0$. Also the sum of the absolute terms $[al] + [bl] + [cl] + \cdots\cdots + [ol] = 0$. The sum of the diagonal coefficients $[oo] + [aa] + [bb] + \cdots\cdots = n - s =$ number of observations — number of series, when all the p's are made unity. Also the sum of the coefficients in formula (7) is zero. By writing out in detail the literal equation corresponding to each of these checks it may be shown to reduce to an identity in each case. Hence the numerical checks will be

completely satisfied, except for the small effects of omitted decimals, if the computation is free from mistakes.

All the observations having been given equal weight the rigorous formula for the probable error e of a single observation of a direction is

$$e^2 = \frac{0{\cdot}455\Sigma v^2}{\text{No. Obs.—No Independent Unknowns}} = \frac{0{\cdot}455\Sigma \varDelta^2}{n - s - d + 1} \dots\dots (8)$$

(8) gives a rigorous determination of e if the observations upon all signals are actually of equal accuracy. If the observations upon different signals are of different degrees of accuracy, even though they have been assigned equal weight, (8) will furnish an average value for e.

To derive ε, the probable error of an adjusted *angle*, by the rigorous method involves so much heavy computation in solving the various weight equations, that one is forced to use some approximate formula for computing it.

Although observations upon different signals (different directions) have been given equal weight in the adjustment, it is nevertheless recognized that a difference of accuracy exists and that it is desirable that it should be taken into account in computing the probable errors. This may be accomplished to a certain extent by making the computed probable error for each direction depend upon the residuals from that direction only, instead of basing it upon the whole group of residuals.

We may assume that e_x^2, the square of the probable error of a single observation upon signal x, is to e^2, the square of the probable error of the average single observation, as the average $\varDelta^2$ upon signal x is to the average $\varDelta^2$ at the station, i. e.,

$$\frac{e_x^2}{e^2} = \frac{\frac{1}{s_x}\Sigma_x \varDelta^2}{\frac{1}{n}\Sigma \varDelta^2} \dots\dots (9)$$

in which s_x is the number of sightings upon signal x and the subscript of the upper Σ indicates that the summation includes only the $\varDelta^2$'s pertaining to the direction x which is being treated.

If (9) is solved for e_x^2 and the value of e^2 is substituted from (8), there is obtained

$$e_x^2 = \frac{0{\cdot}455\Sigma_x \varDelta^2}{n - s - d + 1} \cdot \frac{n}{s_x} \dots\dots (10)$$

If all signals are observed in every series at the station then $n = sd$ and $s = s_x$. After substituting these values for n and s_x (10) may be written

$$e_x^2 = \frac{0{\cdot}455 d \Sigma_x \varDelta^2}{(d - 1)(s - 1)} \dots\dots (11)$$

In the usual case occurring in practice, in which *not all of the signals are observed in each series*, $n < sd$ and $s > s_x$, and the transformation from (10) to (11) is approximate. A detailed comparison of (10) and (11) indicates that for the usual case in practice (11) gives values of e_x^2, which are slightly too small.

Having e_x, the probable error of a single observation upon signal x, the rigorous expression for ε, the probable error of the adjusted angle between signal x and the initial signal, is given by

$$\varepsilon^2 = e_x^2 Q \dots\dots (12)$$

in which Q is the reciprocal of the weight of the adjusted angle and is determined from the following weight equations in which the coefficients are identical with those in (3) and (4).

The weight equations for angle A (second direction) are

$$\left.\begin{array}{l}
[p_1]q_1 \qquad\qquad\qquad + p_1''Q_A + p_1'''q_B + \cdots\cdots = 0 \\
\qquad + [p_2]q_2 \qquad\qquad + p_2''Q_A + p_2'''q_B + \cdots\cdots = 0 \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
p_1''q_1 + p_2''q_2 + \cdots\cdots + [p'']Q_A \cdots\cdots\cdots - 1 = 0 \\
p_1'''q_1 + p_2'''q_2 + \cdots\cdots \qquad + [p''']q_B \quad \cdots\cdots = 0 \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots
\end{array}\right\} \cdots\cdots (13)$$

A similar set of weight equations may be written for each of the other angles B, C, ... in turn.

To solve each set of weight equations of the form indicated in (13) by the usual method of elimination is so heavy a task that an approximate solution must be sought.

The following procedure furnishes a quick solution which is exact when all series are complete, and which is approximate when some of the signals are omitted from some series.

In the first half of equations (13) change all signs—that is, multiply each term by -1; multiply the equation which contains the absolute term -1 by $+2$, and write the remaining equations unchanged. Equations (13) as thus modified are:

$$\begin{array}{l}
-[p_1]q_1 \qquad\qquad\qquad -p_1''Q_A - p_1'''q_B - \cdots\cdots = 0 \\
\qquad -[p_2]q_2 \qquad\qquad -p_2''Q_A - p_2'''q_B - \cdots\cdots = 0 \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
2p_1''q_1 + 2p_2''q_2 + \cdots\cdots + 2[p'']Q_A \qquad\qquad -2 = 0 \\
p_1'''q_1 + p_2'''q_2 + \qquad\qquad\qquad + [p''']q_B \qquad = 0 \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots
\end{array}$$

Adding together all the equations in this group, remembering that the subscript in each case is the number of the series and the superscript is the number of the signal observed upon, and that each p is unity, there is obtained the following equations.

If all series are complete, the addition gives*

$$[p'']Q_A - 2 = 0$$

which may be written

$$sQ_A - 2 = 0$$

whence, without approximation

$$Q = \frac{2}{s} \cdots\cdots\cdots\cdots (14)$$

On the other hand, *if some of the series are incomplete*, the above addition gives

$$\pm q_1 \pm q_2 \pm \cdots\cdots\cdots + [p'']Q_A \qquad -2 = 0 \cdots\cdots (15)$$

*The term involving q_1 disappears in the addition, because $2p_1'' = p_1' + p_1''$ (each p being unity) and hence $2p_1'' + p_1''' + \ldots\ldots = [p_1]$. Similarly the terms involving q_2, q_3......disappear.

in which the coefficients of q_1, q_2, ... are always unity or zero. The coefficient will in each case be $+1$ if the initial signal is not observed in the series in question while the second* signal is observed, will be -1 if the initial is observed but not the second signal, and will be zero if both the initial and the second signal are observed, or if both are omitted.

The form of equations (13) shows that the various q's are in general small in comparison with Q. Also $[p]$ will in general be much greater than unity. Hence it will be a close approximation to drop the terms $\pm q_1 \pm q_2 \ldots\ldots$ from (15) and write

$$[p'']Q_A - 2 = 0$$

whence, as before

$$Q = \frac{2}{s_x} \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

in which s_x is the number of series in which the signal in question was observed.

Equation (12), after introducing the value of e_x^2 from (11) and Q from (14) now becomes, *if all series are complete,*

$$\varepsilon^2 = \frac{2d\,(0{\cdot}455)\,\Sigma_x\Delta^2}{s\,(d-1)(s-1)} \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

From equations (6) it may be seen that the diagonal coefficient in each normal equation (5), viz: $[aa]$, $[bb]$, etc., when all series are complete, is

$$s - \frac{s}{d} = \frac{s\,(d-1)}{d}$$

Hence (17) may be written

$$\varepsilon^2 = \frac{2(0{\cdot}455)\,\Sigma_x\Delta^2}{(s-1)\,(\text{diagonal coefficient})} \ldots\ldots\ldots\ldots\ldots\ldots (18)$$

If some of the series are incomplete, the approximate value of Q from (16) instead of (14) must be substituted in (12), whence there is obtained the approximate formula

$$\varepsilon^2 = \frac{2d\,(0{\cdot}455)\,\Sigma_x\Delta^2}{s_x(d-1)\,(s_x-1)} \ldots\ldots\ldots\ldots\ldots\ldots (19)$$

Also, *approximately*, the diagonal coefficients in (5) are

$$s_x - \frac{s_x}{d} = \frac{s_x\,(d-1)}{d}$$

whence (19) may be written, as an approximation,

$$\varepsilon^2 = \frac{2\,(0{\cdot}455)\,\Sigma_x\Delta^2}{(s_x-1)\,(\text{diagonal coefficient})} \ldots\ldots\ldots\ldots\ldots\ldots (20)$$

Formula (19) is evidently somewhat more accurate than (20).

To sum up, formula (20) may be used for both complete and incomplete series with the understanding that it is exact if all series are complete, but is otherwise approximate only. In this formula $\Sigma_x\Delta^2$ includes only the Δ^2s from pointings upon the particular signal under consideration, s_x is the number of pointings† upon that signal, and the

*The second signal being the one which, with the initial, defines the angle A.

†The mean of two pointings, one in the direct and one in the reverse position of the telescope, being here counted as one pointing.

"diagonal coefficient" is the [*aa*] or [*bb*] .... of the normal equation (5) corresponding to that signal.

It should be kept clearly in mind that the ε is the probable error of the *angle* between the signal under consideration and the initial signal. When for use in the triangulation the angle between, say, O2 and O3 = $(B - A)$, see figure p. 37, is required, it should be noted that angles A and B, as derived from the adjustment, are not independent. The errors due to erroneous pointings upon the initial signal are common to both angles and are canceled out from their difference. Hence, assuming that errors in A are due in equal parts to errors in pointing upon the initial signal and upon the second signal, and similarly for B, we may write

$$\varepsilon^2_{(B-A)} = \tfrac{1}{2}\,(\varepsilon_A^2 + \varepsilon_B^2) \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

The following portions of the local adjustment at the station Mount Helena, California, will serve to illustrate the arrangement of the numerical work.

Abstract of directions.

1876.	Mt. Diablo.	Table Mt.	Snow Mt. (E).	Az. Mark.	Marysville Butte.	Lola.	Pine Hill.	Round Top.	Monticello.	Vaca.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Assumed directions	0 00	33 43	208 37	225 16	265 31	281 54	303 14	305 18	306 46	340 03
	″	″	″	″	″	″	″	″	″	″
	00.0	57.2	44.7	49.5	14.3	43.5	10.2	41.1	16.2	44.3
	″	″	″	″	″	″	″	″	″	″
Arithmetic complement	00.0	02.8	15.3	10.5	45.7	16.5	49.8	18.9	43.8	15.7
		00.0	12.5	07.7	42.9	13.7	47.0	16.1	41.0	12.9
			00.0	55.2	30.4	01.2	34.5	03.6	28.5	00.4
				....	....	....	....	....	....	....
						....	....	....	....	....
		″	″	″	″				″	″
Oct. 11		19.22	07.39	11.27	37.28				36.78	06.02
a. m.		15.56	04.83	09.71	32.43				35.01	05.12
Pos. 12		17.39	06.11	10.49	34.85				35.89	05.57
Series 33		00.00	48.72	53.10	17.46				18.50	48.18
		00.00	01.22	00.80	00.36				59.50	01.08
	″	″		″			″		″	″
Oct. 12	21.64	19.67		15.27			31.79		37.00	05.39
a. m.	17.32	16.10		10.61			29.79		35.06	05.55
Pos. 13	19.48	17.88		12.94			30.79		36.03	05.47
Series 36	00.00	58.40		53.46			11.31		16.55	45.99
	00.00	01.20		03.96			01.11		00.35	01.69
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

The assumed directions A', B', C'.... were taken from the field computation. The arithmetical complements of the seconds of these angles are to be used to transform subtractions into additions. They are given for each signal in turn used as an initial.

In the abstract proper two series only, the thirty-third and thirty-sixth, are here given out of the 152 series shown in the original computation. The first line gives the seconds of the mean reading of the three microscopes for each signal sighted with the telescope direct. The corrections for run have already been applied. The second line gives the corresponding readings with the telescope in the reverse position, when sweeping back over the same signals in the opposite direction. The third line is the mean of the first and second. The fourth line is derived by subtracting the first value in the third line from each of the values on that line. The fifth line is derived by adding to each value in the fourth line the corresponding arithmetical complement from the table shown. The values on the fifth line are the m's of the observation equations (2). To avoid negative signs, 59.50 is understood to be equivalent to −0.50.

An abstract of the m's is next made, as illustrated below. It is made in a rearranged order such as to facilitate the formation of the normal equations (5). All series of pointings upon *nine* signals were placed in the first group (no series included all ten signals), upon *eight* signals in the second group, and so on. Also, within each group all series involving precisely the same combination of signals were placed together.

Abstract of diminished measures.

No. Series.	Mt. Diablo.	Table Mt.	Snow Mt.(E)	Az. Mark.	Marys-ville.	Lola.	Pine Hill.	Round Top.	Monti-cello.	Vaca.	Means.
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
	"	"		"			"		"	"	"
36	00.00	01.20		03.96			01.11		00.35	01.69	+1.385
131	00.00	00.08		58.35			59.62		00.58	59.50	−0.312
......	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
33		00.00	01.22	00.80	00.36				59.50	01.08	+0.493
......	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
Sums.	00.00	+0.98	+4.34	−9.17	+7.37	−12.00	−10.32	−3.54	−10.97	−15.00	
No.	82	60	81	122	56	54	55	50	67	56	

The means of the horizontal lines, as given in the last column, serve to furnish the negative terms in the expression for $[a\,l]$, equations (6), while the sums of the columns, as shown at the bottom, are $[p''\,m'']$, $[p'''\,m''']$, ... The numbers of entries in the separate columns, as shown at the bottom, are $[p']$ $[p'']$ $[p''']$, ...

The normal equations corresponding to (5), as formed from this abstract, are shown below, together with the checks upon their formation.

Normal equations.

	(*A*)	(*B*)	(*C*)	(*D*)	(*E*)	(*F*)	(*G*)	(*H*)	(*I*)	Absolute term.	
	+47·828	− 4·841	− 8·927	− 3·447	− 2·086	− 2·995	− 1·807	− 8·564	− 7·364	+ 3·086	=0
	− 4·841	+62·893	−14·252	− 6·198	− 9·227	− 5·786	− 6·639	− 4·701	− 3·368	−12·040	=0
	− 8·927	−14·252	+90·251	− 8·591	− 8·148	−11·115	− 6·534	−11·960	− 9·427	−12·099	=0
	− 3·447	− 6·198	− 8·591	+44·687	− 3·952	− 5·484	− 4·531	− 3·673	− 3·190	− 8·680	=0
	− 2·086	− 9·227	− 8·148	− 3·952	+41·540	− 3·467	− 5·243	− 2·054	− 1·229	+10·637	=0
	− 2·995	− 5·786	−11·115	− 5·484	− 3·467	+43·082	− 2·945	− 2·920	− 2·795	− 0·942	=0
	− 1·807	− 6·639	− 6·534	− 4·531	− 5·243	− 2·945	+39·328	− 2·283	− 1·750	− 1·089	=0
	− 8·564	− 4·701	−11·960	− 3·673	− 2·054	− 2·920	− 2·283	+51·985	− 8·823	+ 7·764	=0
	− 7·364	− 3·368	− 9·427	− 3·190	− 1·229	− 2·795	− 1·750	− 8·823	+44·218	+11·542	=0
	[*oa*]	[*ob*]	[*oc*]	[*od*]	[*oe*]	[*of*]	[*og*]	[*oh*]	[*oi*]	[*ol*]	
	− 7·797	− 7·882	−11·299	− 5·621	− 6·135	− 5·576	− 7·597	− 7·007	− 6·273	+ 1·822	
Sums	0·000	− 0·001	− 0·002	0·000	0·000	− 0·001	− 0·001	0·000	− 0·001	+ 0·001	

[*aa*] = + 47·828	[*oa*] = − 7·797	″		″
[*bb*] = + 62·893	[*ob*] = − 7·882	[*A*] = − 0·058		− 0·008
[*cc*] = + 90·251	[*oc*] = − 11·299	[*B*] = + 0·212		+ 0·027
[*dd*] = + 44·687	[*od*] = − 5·621	[*C*] = + 0·143		+ 0·002
[*ee*] = + 41·540	[*oe*] = − 6·135	[*D*] = + 0·223	Residuals from normal equations.	− 0·009
[*ff*] = + 43·082	[*of*] = − 5·576	[*E*] = − 0·159		+ 0·017
[*gg*] = + 39·328	[*og*] = − 7·597	[*F*] = + 0·080		− 0·017
[*hh*] = + 51·985	[*oh*] = − 7·007	[*G*] = + 0·077		− 0·013
[*ii*] = + 44·218	[*oi*] = − 6·273	[*H*] = − 0·129		− 0·025
[*oo*] = + 65·187	[*oo*] = + 65·187	[*I*] = − 0·230		+ 0·001
+ 152·000 = No. of series.	0·000 = Sum.			
− 683·000 = No. of observations.				
− 0·001 = Sum.				

The "residuals from normal equations" were obtained by substituting the adopted values for (*A*), (*B*)....in the normal equations.

The values of (*A*), (*B*) .... being substituted in the "abstract of diminished measures" there is obtained an "abstract of remaining differences" written in precisely the same form. In this latter abstract if the mean of the horizontal line as given in the last column is subtracted from each of the individual values in that line the differences are the Δ's from which the probable errors are computed by (20) and (21).

A portion of the abstract of remaining differences and of the abstract of values of Δ and Δ^2 is shown below.

Abstract of remaining differences—Mount Helena.

No. Series.	Mount Diablo.	Table Mountain.	Snow Mt. (E).	Az. Mark.	Marysville.	Lola.	Pine Hill.	Round Top.	Monticello.	Vaca.	Means.
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
36	00·00	01·26		03·82			01·03		00·48	01·92	01·42
131	00·00	00·14		58·21			59·54		00·71	59·73	59·72
....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
33		00·06	01·01	00·66	00·14				59·63	01·31	00·47
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Abstract of values of $\varDelta$ and $\varDelta^2$—Mount Helena.

No. Series.	Mount Diablo.		Table Mount'n.		Snow Mt. (E)		Az. Mark.		Marysville.		Lola.		Pine Hill.		Round Top.		Monticello.		Vaca.		
	Δ	Δ^2	Δ	Δ^2	Δ	Δ^2	Δ	Δ^2	Δ	Δ^2	Δ	Δ^2	Δ	Δ^2	Δ	Δ^2	Δ	Δ^2	Δ	Δ^2	
	......	...	......	...	......	...	....	...	......	...	......	...	......	...	......	...	......	...	......	...	
36	−1·42	2·0	−·16	0·0			+2·40	5·8					−·39	0·2			−·94	0·9	+·50	0·3	
131	+·28	0·1	+·42	0·2			−1·51	2·3					−·18	0·0			+·99	1·0	+·01	0·0	
....	......	...	......	...	......	...	......	...	......	...	......	...	......	...	......	...	......	...	......	.	
33			−·41	0·2	+·54	0·3	+·19	0·0	−·33	0·1							−·84	0·7	+·84	0·7	
	......	...	......	...	......	...	......	...	......	...	......	...	......	...	......	...	......	...	......	...	
Sums..		38·5		31·6		38·4		64·9		32·8		33·4		34·9		23·1		43·2		67·9	$\Sigma\Delta^2 = 408·7$
No.....		82		60		81		122		56		54		55		50		67		56	

Hence the probable error of a single observation of a direction is by formula (8)

$$e = \sqrt{\frac{0·455\ \Sigma\varDelta^2}{n - s - d + 1}} = \sqrt{\frac{(0·455)\ (408·7)}{683 - 152 - 10 + 1}} = \pm 0''·60$$

The probable error of the angle between Table Mountain and Mt. Diablo is, by formula

$$(20),\ \varepsilon = \sqrt{\frac{0·910\ \Sigma_x\varDelta^2}{(s_x - 1)\ (\text{diagonal coefficient})}} = \sqrt{\frac{(0·910)\ (31·6)}{(60)\ (47·8)}} = \sqrt{0·0100} = \pm 0''·10$$

similarly the probable error of the angle between Snow Mountain and Mount Diablo is

$$\sqrt{\frac{(0·910)\ (38·4)}{(81)\ (62·9)}} = \sqrt{0·0069} = \pm 0''·08$$

By formula (21) the probable error of the angle between Table Mountain and Snow Mountain is

$$\sqrt{\tfrac{1}{2}\,(0·0100 + 0·0069)} = \pm 0·09$$

In case of the adjustment of the Yolo Base net, already referred to above as the only one where special weights to the resulting directions from station adjustments were introduced in the net adjustment, these weights were not those obtained by $p = \frac{1}{\varepsilon_1^2}$ as roughly approximate values, but they were modified by adding to the respective probable error a constant one depending on the closing of the triangles. This latter probable error is shown to be much greater than the above ε_1 and the effect was to tone down the variations in the respective final weights to the directions. In connection with this it may be noted that the influence of weights rather diminishes with an increased geometric complexity of the net. For particulars of the treatment of the Yolo Base net, see Appendix No. 9, report for 1885.

The value of e, or the probable error ($p.\ e.$) of a single observation of a direction at a station, as given along with the abstract of the directions at the station, merely serves the purpose of giving some general information bearing upon the accuracy of the means employed.

(D.) REDUCTION OF HORIZONTAL DIRECTIONS TO SEA LEVEL.

The resulting directions at a station, as given in the abstracts, still need a small correction to reduce them to what they would have been had the object observed upon been at the sea level. The altitude of the observing station and the distance between them does not enter into the case; the reduction is due to the circumstance that, in general, the verticals at the two stations are not in the same vertical plane. The correction * is given by $\frac{e^2}{2} \cdot \frac{h}{\rho} \sin 2\alpha \,.\, \cos^2\phi$, where $e^2 = \frac{a^2 - b^2}{a^2}$ and h = altitude of the station observed upon. ρ = radius of curvature in the plane normal to the meridian, α = azimuth of the line (counted from south around by west) and ϕ = latitude of place. With $\log e^2 = \bar{7}{\cdot}8305$ and $\log \rho = 6{\cdot}8054$ for $\phi = 39°$ and Clarke's spheroid (of 1866), and dividing the expression by $\sin 1''$, we get for the correction in seconds and the height in metres

$$0''{\cdot}000\ 066 \sin 2\alpha . h$$

This correction has been applied systematically to all measured directions of the base nets and intervening triangulation from the Salina base to the Pacific coast, but no application was made to the triangulation east of Salina base on account of the lower altitudes and consequent smallness of the correction in this part of the arc. In comparison with the magnitude of the average triangle closing error, the effect of omitting this correction, except for the higher altitudes, seems justified. About the Salina base stations the average reduction of a sight to the sea level is but $0''{\cdot}02$.

The probable error of a single observation of a direction (e) is given under the list of directions at each station as a convenient index of the accuracy of the observations. When the parenthesis (*D.* and *R.*) is used, the observations were made with a direction instrument. A single observation of a direction comprises two pointings upon the signal, one with telescope direct and one with telescope reversed, and two readings (forward and backward) of each microscope, of which there are usually three, for each pointing. e is computed by formula (8) shown on page 40.

When the parenthesis (6 *D.* and 6 *R.*) is used, the observations were made with a repeating instrument and a single observation *of an angle* comprises 12 pointings upon each of two signals, 6 with telescope direct and 6 reversed, and 3 readings of the horizontal circle, at the beginning and end of the direct measure and again at the end of the reversed measure. The quantity given is the probable error of a single observation of a *direction* (not angle) and is $\frac{1}{\sqrt{2}}$ times the probable error of a single observation of an angle.

It was also computed by the formula (8) shown on page 40.

The parenthesis (3 *D.* and 3 *R.*) has a meaning analogous to (6 *D.* and 6 *R.*).

(E.) ADJUSTMENT OF BASE NETS OR OTHER TRIANGULATIONS.

The method is the same as that usually employed to satisfy the geometrical conditions of a triangulation by application of the method of least squares. For the sake of convenience the leading formulæ referring to condition observations, together

* "Geodesy," by Col. A. R. Clarke, Oxford, 1880, p. 113.

with those for the computation of the probable error of a function of the adjusted quantities, will be briefly recapitulated here.*

Suppose we have given as the direct result of observation the m quantities $l_1\ l_2\ l_3 \ldots$ which are connected by n conditions. Let $x_1\ x_2\ x_3 \ldots$ be their most probable values; also let $v_1\ v_2\ v_3 \ldots$ be the corrections to the observed values, so that in general we have $x_i = l_i + v_i$; remembering that necessarily $m > n$ in order that any adjustment may exist, then the conditions involved may be expressed by n equations, of linear form, thus:

$$
\begin{aligned}
0 &= a_0 + a_1x_1 + a_2x_2 + a_3x_3 + \ldots \\
0 &= b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \ldots \\
0 &= c_0 + c_1x_1 + c_2x_2 + c_3x_3 + \ldots \\
&\ldots\ldots\ldots
\end{aligned}
$$

Introducing the observed quantities these equations will not be satisfied, but will leave the discrepancies $w_1\ w_2\ w_3 \ldots\ldots$ viz:

$$
\begin{aligned}
w_1 &= a_0 + a_1l_1 + a_2l_2 + a_3l_3 + \ldots \\
w_2 &= b_0 + b_1l_1 + b_2l_2 + b_3l_3 + \ldots \\
w_3 &= c_0 + c_1l_1 + c_2l_2 + c_3l_3 + \ldots \\
&\ldots\ldots\ldots
\end{aligned}
$$

where the sign of w_i is to be taken in the sense of observed value minus true value. We have then the n condition equations:

$$
\begin{aligned}
a_1v_1 + a_2v_2 + a_3v_3 + \ldots\ldots + w_1 &= 0 \\
b_1v_1 + b_2v_2 + b_3v_3 + \ldots\ldots + w_2 &= 0 \\
c_1v_1 + c_2v_2 + c_3v_3 + \ldots\ldots + w_3 &= 0 \\
\ldots\ldots\ldots
\end{aligned}
$$

Let $p_1\ p_2\ p_3 \ldots$ be the weights of the quantities $l_1\ l_2\ l_3 \ldots$ then the quantity $[p.\ vv]$ must be made a minimum; this leads to the equations of correlates which introduce the multipliers $C_1\ C_2\ C_3 \ldots$ as yet unknown. These correlate equations are:

$$
\begin{aligned}
p_1v_1 &= a_1C_1 + b_1C_2 + c_1C_3 + \ldots \\
p_2v_2 &= a_2C_1 + b_2C_2 + c_2C_3 + \ldots \\
p_3v_3 &= a_3C_1 + b_3C_2 + c_3C_3 + \ldots \\
&\ldots\ldots\ldots
\end{aligned}
$$

and the normal equations become

$$
\begin{aligned}
\left[\frac{aa}{p}\right]C_1 + \left[\frac{ab}{p}\right]C_2 + \left[\frac{ac}{p}\right]C_3 + \ldots + w_1 &= 0 \\
\left[\frac{ab}{p}\right]C_1 + \left[\frac{bb}{p}\right]C_2 + \left[\frac{bc}{p}\right]C_3 + \ldots + w_2 &= 0 \\
\left[\frac{ac}{p}\right]C_1 + \left[\frac{bc}{p}\right]C_2 + \left[\frac{cc}{p}\right]C_3 + \ldots + w_3 &= 0 \\
\ldots\ldots\ldots
\end{aligned}
$$

* *Cf.*—T. W. Wright's Treatise on the Adjustment of Observations, New York, 1884, Chapter V, p. 213 and fol., and W. Jordan's Vermessungskunde, Vol. 1 (1888), p. 104 and fol.

which may be written, putting $\mu = 1/p$

$$\begin{aligned}
[\mu.aa]\, C_1 + [\mu.ab]\, C_2 + [\mu.ac]\, C_3 + \ldots + w_1 &= 0 \\
+ [\mu.bb]\, C_2 + [\mu.bc]\, C_3 + \ldots + w_2 &= 0 \\
+ [\mu.cc]\, C_3 + \ldots + w_3 &= 0 \\
+ \ldots &
\end{aligned}$$

Solving these equations the values of C_i become known, and consequently also the values of v_i and x_i.

The mean error of an observation of unit weight is given by $m_1 = \sqrt{\frac{[pvv]}{n}}$ where the sum $[pvv]$ is found by means of the individual corrections and checked in the case of the base nets by the relation $[pvv] = -[wC]$

To find the weight and probable error of an adjusted value of an observation, also the weight P of any function of the adjusted observations, we put

$$F = f_1 x_1 + f_2 x_2 + f_3 x_3 + \ldots$$

which function can not contain all the x's, but only $m - n$ of them.

The coefficients f_i are found by partial differentiation, viz:

$$\frac{\partial F}{dx_1} = f_1 \qquad \frac{\partial F}{dx_2} = f_2 \qquad \frac{\partial F}{dx_3} = f_3, \text{ etc.}$$

We next form the sums

$$\left[\frac{af}{p}\right], \left[\frac{bf}{p}\right], \left[\frac{cf}{p}\right] \text{ etc., also } \left[\frac{ff}{p}\right]$$

and combine them with the former normal equations, at the same time introducing a new set of indeterminate quantities $R_1\ R_2\ R_3 \ldots$ in the place of the former $C_1\ C_2\ C_3 \ldots$ then the requirement of the conditioned minimum leads to the following so called transfer equations:

$$\begin{aligned}
[u.aa]\, R_1 + [u.ab]\, R_2 + [u.ac]\, R_3 + \ldots\ldots + [u.af] &= 0 \\
+ [u.bb]\, R_2 + [u.bc]\, R_3 + \ldots\ldots + [u.bf] &= 0 \\
+ [u.cc]\, R_3 + \ldots\ldots + [u.cf] &= 0 \\
+ \ldots\ldots &
\end{aligned}$$

Solving we have the values R_i, and consequently also F_i by the relations

$$\begin{aligned}
F_1 &= f_1 + a_1 R_1 + b_1 R_2 + c_1 R_3 + \ldots \\
F_2 &= f_2 + a_2 R_1 + b_2 R_2 + c_2 R_3 + \ldots \\
F_3 &= f_3 + a_3 R_1 + b_3 R_2 + c_3 R_3 + \ldots \\
&\ldots\ldots\ldots\ldots\ldots\ldots
\end{aligned}$$

and finally we have the reciprocal of the weight P of the function F by $\frac{1}{P} = [u.FF]$ Also the mean error of

F or $m_F = \frac{m_1}{\sqrt{P}} = m_1 \sqrt{[u.FF]}$ and the probable error of F or $r_F = 0{\cdot}6745\, m_F$

(F.) REMARKS ON WEIGHT COEFFICIENTS IN THE NET ADJUSTMENT AS DEPENDING ON THE STATION ADJUSTMENTS.

In accordance with Bessel's method of proceeding, the corrections as determined in the net adjustment depend with respect to weights on coefficients furnished by the general solution of the station or local adjustments; although theoretically strict, this proceeding has in later times either been greatly modified or abandoned for reasons imposed by practical considerations. It has been from the beginning the practice on the Survey to treat these adjustments independently of each other and to give equal or nearly equal weight to the directions in the net adjustment. This separate treatment is justified by the following consideration: The errors incident to the angular measures as indicated by the local adjustment either depend on other causes or at most are of a subordinate character to the error in the subsequent operation—that is, in the net adjustment. In the latter combination of the measures new sources of error show their effects; as, for instance, the effect of the deflection of the plumb line causing the angles to be measured out of the normal horizontal plane, want of coincidence of the center of a station and of heliotropes or targets subsequently mounted over it, persistent lateral deviation of the line of sight, constant or uncompensated graduation errors of the instrument, all of which causes exert no influence on the station adjustment. It is a matter of experience that the value of the probable error of a direction derived from the measures at a station is much smaller than the same when derived from the triangle closing errors—thus if weights are introduced at all they should be made to exert but a comparatively weak influence. As an example of the process followed, the adjustment of the Yolo Base net may be referred to (Coast and Geodetic Survey Report for 1885. Appendix 9, pp. 447–448).

Let e_s = average value of the probable error of a direction as derived from the station adjustment. e_t = average value of the same as derived from the closing errors of the triangles composing the net. Put $e_c^2 = e_t^2 - e_s^2$. e_c^2 is a constant quantity for the figure under consideration, and is to be combined with every probable error of observation e_s in order to obtain the appropriate probable error and consequent weight of each direction as needed for the figure adjustment. Hence we have $e^2 = e_s^2 + e_c^2$ and the weight $p = \frac{1}{e_s^2 + e_c^2}$. In this manner the weights from the station adjustment are made to undergo a considerable equalization.* In connection with the above consideration we may note also the important feature that the process theoretically called for, involving the introduction of weight equations from the local adjustment, becomes prohibitive for any extended triangulation on account of the excessive labor introduced thereby. The modified weights $p = \frac{1}{e_s^2 + e_c^2}$ are introduced in the adjustment of the triangulation between El Paso and Yolo Base nets, whereas in other parts of the triangulation equal or unit weights are assigned to all directions.

* We have the following values of e_s and e_t in the western section of the arc:

Locality.	Number of directions.	Resulting e_s. ″	Number of triangles.	Resulting e_t. ″
El Paso base net	..	....	16	±0·32
Triangulation El Paso to Salt Lake	67	±0·094	23	±0·27
Salt Lake base net	56	±0·088	33	±0·28
Triangulation Salt Lake to Yolo	90	±0·080	30	±0·20
Yolo base net	34	±0·081	19	±0·24

(G.) THE COMPUTATION OF THE SPHERICAL EXCESS OF THE TRIANGLES.

For all that part of the triangulation which lies east of the Rocky Mountains, and which traverses the plains and gentle slopes of Kansas, Missouri, and Ohio, the comparative shortness of the sides of the triangles admits of the application of Legendre's theorem in its simple form. The spherical excess ε (in seconds) is given by $\frac{a_1 b_1 \sin C_1}{2r^2 \sin 1''}$, where $a_1 b_1 C_1$ refer to sides and included angle of a *plane* triangle, whose angles are those of the corresponding small spherical triangle after each has been diminished by $\frac{1}{3}\,\varepsilon$. When greater precision is required as for the larger triangles which stretch across the peaks and ridges of the Allegheny Range, we introduce the radius of an osculating sphere (referring to the center of the triangle) and take

$$\varepsilon = \frac{a_1 b_1 \sin C_1}{2\rho_m \rho_n \sin 1''} = \frac{a_1 b_1 \sin C_1}{2a^2 (1 - e^2) \sin 1''} \left[1 - e^2 \sin^2\phi\right]^2$$

The quantity $\frac{[1 - e^2 \sin^2\varphi]^2}{2a^2 (1 - e^2) \sin 1''}$ has been tabulated with the latitude φ as argument, for which see Coast and Geodetic Survey annual report for 1894.*

For triangles of unusually large size and approaching the limit for possible observation, certain terms in the development of the theorem which ordinarily could be neglected need examination. It has been shown that spheroidal triangles may be computed as spherical and hence as plane ones by application of the same theorem extended.† Various forms have been given to the development of the theorem.‡ Let

S_1 = surface of the corresponding plane triangle = $\frac{1}{2}\, a_1\, b_1 \sin C_1$,
and let $m^2 = \frac{1}{3}\,(a_1^2 + b_1^2 + c_1^2)$, then

$$\varepsilon'' = \frac{S_1}{\rho_m \rho_n \sin 1''}\left(1 + \frac{m^2}{8\rho_m \rho_n} + \ldots\right)$$

where ρ_m and ρ_n are the radii of curvature in the plane of the meridian and normal to it, and ε is to be distributed unequally over the angles,§ viz:

$$\begin{aligned}
A - A_1 &= \frac{\varepsilon}{3} + \frac{\varepsilon}{60} \cdot \frac{m^2 - a_1^2}{\rho_m \rho_n} + \ldots \text{ or } \frac{\varepsilon}{3}\left(1 + \frac{m^2 - a_1^2}{20\,\rho_m \rho_n}\right) \\
B - B_1 &= \frac{\varepsilon}{3} + \frac{\varepsilon}{60}\, \frac{m^2 - b_1^2}{\rho_m \rho_n} + \ldots \qquad \frac{\varepsilon}{3}\left(1 + \frac{m^2 - b_1^2}{20\rho_m \rho_n}\right) \\
C - C_1 &= \frac{\varepsilon}{3} + \frac{\varepsilon}{60}\, \frac{m^2 - c_1^2}{\rho_m \rho_n} + \ldots \qquad \frac{\varepsilon}{3}\left(1 + \frac{m^2 - c_1^2}{20\rho_m \rho_n}\right)
\end{aligned}$$

A convenient logarithmic formula has been given by the late C. H. Kummell, tables of the factors log A and log B of the Coast and Geodetic Survey method for the

*Appendix No. 9, pp. 290–291.

†The spherical excess of a spheroidal triangle is equal to that of a spherical triangle whose angular points have the same latitudes and longitudes as the corresponding points of the spheroidal triangle—Clarke's Geodesy (1880), pp. 49 and 107.

‡Helmert's Theorieen der Höheren Geodäsie (1880), vol. 1, pp. 88–101.

§Helmert, ibid, p. 98.

computation of geographical positions being on hand (Appendix No. 9, report for 1894). Put in the latest form given by him,* let Δ = area of the plane triangle,

$$\log m = \log A + \log B + \bar{4}.384\ 545$$

$$\log \varepsilon = \log m + \log 2\,\Delta + \frac{\varepsilon}{6}\Sigma \log \text{diff. } 1'' \text{ for the three angles.}$$

For the larger triangles within the region of the Rocky Mountains and of the Sierra Nevada the spherical excess rises to 1′, and even exceeds this amount. To show the effect of the higher terms, also the change of ε when computed for the Clarke and the Bessel spheroids,† the following example has been added. For the largest triangle—Tushar, Wheeler Peak, Mount Nebo—we have the following approximate data, and for distances given in metres—

	Distance.	
$\log a_1 = \log$ (Wheeler P. to Mt. Nebo)	$= 5.376\ 1460$	
$\log c_1 = \log$ (Wheeler P. to Tushar)	$= 5.247\ 8364$	
$\log b_1 = \log$ (Mt. Nebo to Tushar)	$= 5.215\ 5124$	
C_1	$= 48^\circ\ 03'\ 40''.987$	
$\log a_1 b_1 \sin C_1$	$= 10.463\ 150$	
$\log 1/2\, \rho_m \rho_n \sin 1''$	$= \bar{1}.404\ 610$ (see table appended)	
log first term	$= 1.867\ 760$	First term $73''.7497$
$\log m^2$	$= 10.583$	
$\log \rho_m \rho_n$	13.609	
log 8	0.903	
$\log m^2/8\, \rho_m \rho_n$	$\bar{6}.071$	
log first term	1.868	
log second term	$\bar{7}.939$	Second term $= 0.0087$
		$\varepsilon = 73.7584$

		°	′
Lat. of Tushar		38	25.1
Lat. of Wheeler P.		39	48.5
Lat. of Mt. Nebo		38	59.1
φ_m		39	04
$\log (m^2 - a_1^2) =$	$_n10.26$		
$\log 1/20\, \rho_m \rho_n =$	$\bar{5}.09$		
	$_n\bar{5}.35$		
$\log \frac{1}{3}\varepsilon$	1.39		
Similarly—			″
$\log\left(A - A_1 - \frac{\varepsilon}{3}\right)$	$_n\bar{6}.74$		-0.00055
$\log\left(B - B_1 - \frac{\varepsilon}{3}\right)$	$\bar{6}.32$		$+0.00021$
$\log\left(C - C_1 - \frac{\varepsilon}{3}\right)$	$\bar{6}.53$		$+0.00034$
			Check sum $= 0$

and the distribution to the spherical angles becomes

	″
to A	-24.5856
to B	-24.5863
to C	-24.5864
sum	73.7583

This example shows that on account of the second term the third place in the decimals of the difference between the spherical and plane angles is not affected by as much as a unit.

Difference in the above value of ε due to a change of reference spheroid.

* Astronomische Nachrichten No. 2116.

† We have $\frac{d\varepsilon}{\varepsilon} = -\frac{2da}{a} + 2 \cos 2\varphi e de$. (See Die "geodätischen Hauptpunkte," etc. Von G. Zachariae, translation by Dr. E. Lamp, Berlin, 1878, pp. 302-303.)

By direct computation the values stand as follows: *

	Clarke spheroid	Bessel spheroid.
log a_1 b_1 sin C_1	10·463 150	10·463 150
log 1/2 ρ_m ρ_n sin 1″	$\bar{1}$·404 610	$\bar{1}$·404 711
log first term	1·867 760	1·867 861
First term	73″·749 7	73·766 8
Second term	+0·008 7	+0·008 7
Resulting ε	73″·758 4	73″·775 5

The difference in the value of ε is 0″·017 1, or $\frac{1}{4314}$ part of itself.

The computation of ε according to Kummell's logarithmic form stands as follows:

	°	′	″
Angle at Tushar	88	16	06
Angle at Wheeler	43	40	13
Angle at Mt. Nebo	48	03	41

log diff. 1″ in seventh place of dec's.	+ 1
	+22
	+19
Sum	42
⅙ sum	7

log A=	$\bar{8}$.509 142
log B	8·510 922
log const.	$\bar{4}$·384 545
log m	$\bar{1}$·404 609

} From table app. 9, rep. for 1894.

log a_1	= 5·376 146
log b_1	5·215 512
log sin C_1	9·871 492
log 2Δ	10·463 150

log ⅙ sum	0·845 1
log 1st + 2d term	1·867 8
516	2·712 9

log 2$\triangle$	10·463 150
log 1st + 2d term	1·867 759 or 73″·749 5
3d term	+ 52

Resulting log ε 1·867 811 and ε = 73″·758 3 as before

Values of log $1/2\rho_m\rho_n$ sin 1″ for the spheroids of Clarke (1866) and Bessel (1841) and argument ϕ between latitudes $\phi = 30°$ and $\phi = 50°$.

Here ρ_m = radius of curvature in the meridian and ρ_n radius of curvature in the plane normal to it; the dimensions of the spheroids are those given in Appendix No. 9, Report for 1894, p. 280, and are expressed in metres.

ϕ	Clarke's spheroid.			Diff. for 1′ in 6th place.	Bessel's spheroid.†			Diff. for 1′ in 6th place.
	log ρ_m	log ρ_n	log 1/2 ρ_m ρ_n sin 1″		log ρ_m	log ρ_n	log 1/2 ρ_m ρ_n sin 1″	
°								
30	6·802 852	6·805 066	$\bar{1}$·405 477	1·50	6·802 823	6·805 006	$\bar{1}$·405 566	1·48
31	2 919	5 089	387	1·53	2 890	5 028	477	1·50
32	2 988	5 112	295	1·55	2 957	5 051	387	1·53
33	3 058	5 135	202	1·58	3 026	5 074	295	1·55
34	3 129	5 159	107	1·60	3 096	5 097	202	1·58
35	3 201	5 183	$\bar{1}$·405 011	1·62	3 167	5 121	107	1·60
36	3 274	5 207	$\bar{1}$·404 914	1·63	3 239	5 145	$\bar{1}$·405 011	1·62
37	3 348	5 231	816	1·65	3 312	5 169	$\bar{1}$·404 914	1·63
38	3 422	5 256	717	1·67	3 385	5 194	816	1·63
39	3 497	5 281	617		3 459	5 218	718	

* For computation by the formula for $\frac{d\varepsilon}{\varepsilon}$ we have: $da = -809{\cdot}2$, $\frac{da}{a} = -0{\cdot}000\ 127$, $de = -0{\cdot}000\ 56$, and $ede = -0{\cdot}000\ 046$; hence $\frac{d\varepsilon}{\varepsilon} = +0{\cdot}000\ 234$, or $d\varepsilon = +0''{\cdot}017\ 2$.

† See Table 35e of radii of curvature in Dr. Albrecht's Formeln und Hülfstafeln für geographische Ortsbestimmungen; Leipzig, 1894, pp. 268–269.

φ	Clarke's spheroid.			Diff. for 1′ in 6th place.	Bessel's spheroid.			Diff. for 1′ in 6th place.
	log ρ_m	log ρ_n	log 1/2 ρ_m ρ_n sin 1″		log ρ_m	log ρ_n	log 1/2 ρ_m ρ_n sin 1″	
°				1·70				1·67
40	3 573	5 307	515	1·70	3 534	5 243	618	1·67
41	3 650	5 332	413	1·70	3 609	5 268	518	1·68
42	3 726	5 358	311	1·70	3 685	5 293	417	1·70
43	3 803	5 383	209	1·72	3 761	5 319	315	1·68
44	3 880	5 409	106	1·72	3 837	5 344	214	1·68
45	3 957	5 435	$\bar{1}$·404 003	1·72	3 913	5 369	113	1·70
46	4 035	5 460	$\bar{1}$·403 900	1·72	3 989	5 395	$\bar{1}$·404 011	1·68
47	4 112	5 486	797	1·72	4 065	5 420	$\bar{1}$·403 910	1·68
48	4 189	5 512	694	1·70	4 141	5 445	809	1·68
49	4 265	5 537	592	1·70	4 216	5 471	708	1·68
50	4 342	5 563	490		4 292	5 496	607	

(H.) ACCOUNT OF THE BASE LINES,

their positions, apparatus used, measurements, resulting lengths and probable errors, together with the abstracts of angles and adjustment of triangles forming the base nets, with description of stations composing the same.

GENERAL STATISTICS OF THE BASE LINES, ARRANGED IN THE ORDER OF TIME OF MEASUREMENT.

Table I.

No.	Name of line.	State.	Date of measure.	Chief of party.	Apparatus used.
1	The Kent Island Base	Md.	1844, May and June.	J. Ferguson	The Hassler base apparatus, 4 iron bars of 8-metre joint length, optical contact.
2	The American Bottom Base	Ill.	1872, Oct. and Sept.	C. H. Boyd	The 6-metre contact-slide iron rods Nos. 1 and 2.
3	The Olney Base	Ill.	1879, July to Sept.	E. S. Wheeler*	The Repsold 4-metre steel and zinc combined bar, optical contact.
4	The El Paso Base	Colo.	1879, Aug. and Sept.	O. H. Tittmann	The 6-metre steel contact-slide rods Nos. 3 and 4.
5	The Yolo Base	Cal.	1881, Sept., Oct., Nov.	G. Davidson	Schott's 5-metre contact-slide compensating steel and zinc bars Nos. 1 and 2.
6	The Holton Base	Ind.	1891, July, Aug., Sept.	A. T. Mosman	The 5-metre contact-slide steel rods Nos. 13 and 14 and steel tape measures, also used in part, steel bar No. 17, in ice.
7	The St. Albans Base	W. Va.	1892, October	R. S. Woodward	Two 100-metre steel tapes Nos. 85 and 88.
8	The Salina Base	Kans.	1896, June and July	F. D. Granger	The 5-metre contact-slide steel rods Nos. 13 and 14.
9	The Salt Lake Base	Utah	1896, Sept. and Oct.	W. Eimbeck	Eimbeck's 5-metre contact-slide duplex apparatus, steel and brass rods.
10	The Versailles Base	Mo.	1897, June	A. L. Baldwin	The 5-metre contact-slide rods Nos. 13 and 14, and the 50-metre steel tape No. 204.

* Gen. C. B. Comstock, U. S. E., in charge United States Lake Survey.

2. THE MEASUREMENT OF THE BASE LINES.

The measure of the linear extent of the triangulation, or what comes here to the same thing, the width of the country, is made to depend on the measure of 10 base lines located at suitable distances and connected with the triangulation by means of base nets. Through these nets, by gradual expansion, the comparatively short length of a base is developed to that of the sides of the principal triangles. The bases were measured with a variety of apparatus and in time range over a period of fifty-three years, the first one having been measured long before the survey across the country was contemplated.

In what follows we shall give for each base complete, yet brief, information respecting: The geographic position, nature of the ground traversed, its altitude above the sea, description and standardization of the apparatus, observer and method of measure, resulting length with probable error, and other matter pertinent thereto. This is followed by abstracts of the angular measures at the stations composing the net, by its adjustment and final length of its triangle sides; finally there is given the probable error of the sides of the net which bind it to the main triangulation on both sides of it.

(a) *Kent Island Base Line, Maryland, 1844.*

LOCATION, MEASUREMENT, AND LENGTH.

Kent Island, in Queen Anne County, Maryland, on the western shore of which the base was measured, is situated on the east side of Chesapeake Bay and nearly opposite Annapolis Harbor, Maryland. Originally the base in this locality was intended to serve as a check on the length of the sides of the primary triangulation brought south from Fire Island, New York, and to provide a basis for the triangulation of the Chesapeake Bay, but its situation close to the parallel of 39° has made it available for the transcontinental triangulation, proposed more than a quarter of a century later. The surface of this part of the island is slightly undulating, composed mostly of cultivated fields, but in parts swampy and wooded. It is little elevated above the mean sea level. The northern terminal monument was placed near Broad Creek, and its foundation was laid in the sand, one and a half metres below the surface, with a course of rubble masonry. The end point of the base was marked by copper bolts in a stone slab below and an upright stone above ground. The southern terminus at Prices Creek was similarly marked, and both monuments were finally covered with an earthen mound for further protection. When visited in 1888, it was found that the shore of the southern part of the island had been washed away and that the southern monument had disappeared below the waves.

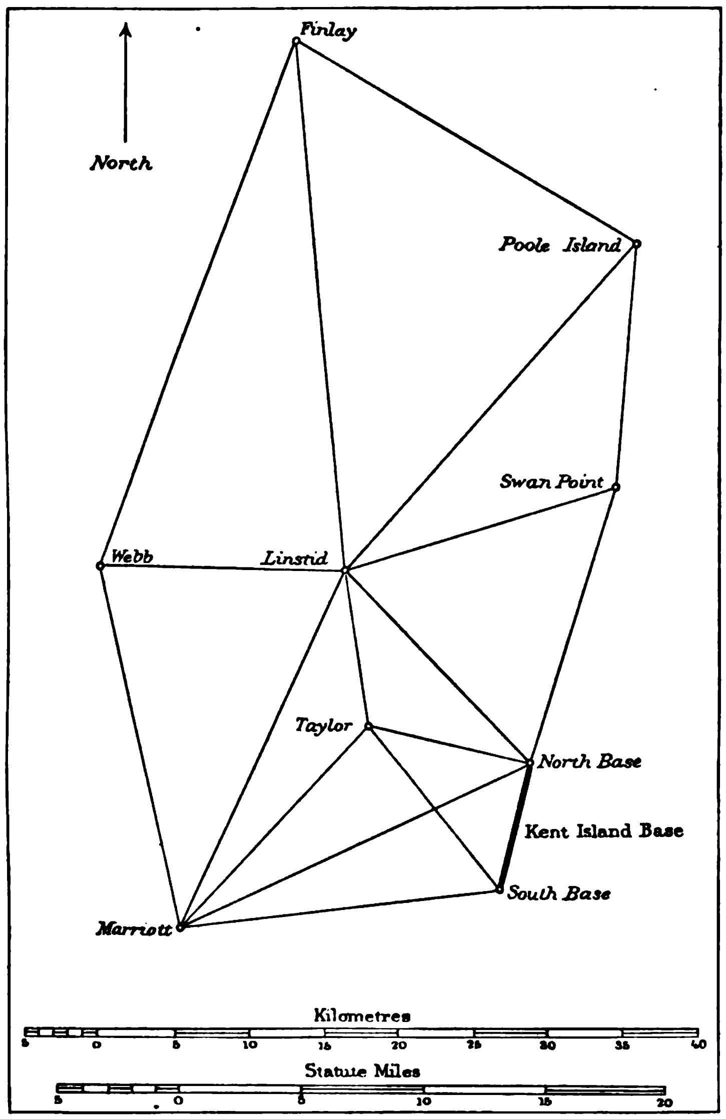
The length of the base is 8⅔ kilometres, or nearly 5·4 statute miles; its middle point is in latitude 38° 56′ about, in longitude 76° 21′, and the azimuth of the line from the southern end is 194° 35′ nearly. The alignment of the base was made by placing a theodolite over a point near its middle, and marking out the line by flags.

The measurement of the base was intrusted by Superintendent Bache to Assistant James Ferguson, aided by Mr. R. D. Cutts, who made a preliminary measure and drove stakes at every 200 metres of the line.

The apparatus used was that known as the Hassler Base Apparatus. It is described in the Transactions of the American Philosophical Society (Philadelphia) for the year

1825, pp. 273–286 (illustrated by Plate III), and had been used for the measure of the Fire Island base by Superintendent Hassler in 1834. It consists of a box in which are placed, in line, 4 rectangular iron bars, each 2 metres long, the joined length being 8 metres. Over the forward end of the box a microscope was mounted on a tripod, the cross hairs of which served again as a fixed point when the rear end of the box was later brought under the same fiducial lines of the microscope. The focus of the fixed microscope was never changed after it had once been placed in position. The level of the combination of bars was indicated by means of a sector attached to one of the bars (A) and their temperature was indicated by means of thermometers. At distances of 1 kilometre two stakes were driven, one on each side of the line, but no permanent marks were left; there is, however, a stoneware cone in line 1 kilometre from the north end. Transfers of the end of a bar to ground at the close of a day's work were made either by means of a plummet or by means of a theodolite. But one measure was made, and the time occupied was between May 3 and June 5, 1844.

No. 3.



The 2-metre iron bars, known as the Hassler bars A, B, C, D, were made by Troughton & Simms about 1813, and were standardized in February and March, 1817, by means of the committee metre, which is of the same cross section (27·5 by 9 millimetres) and the iron Lenoir Metre—all the bars being *à bout*. Hassler again determined their length in May, 1834, and in March, 1835, with the aid of the Troughton scale.

In May, 1844, and January, 1845, Messrs. J. Saxton and W. Würdemann and Superintendent A. D. Bache again compared them by means of a Bessel comparator.

The values were:

$$\begin{array}{lll} \text{In } 1817, & \Sigma = 7\cdot999\ 950\ 6\,m & \text{at } 0^\circ C. \\ 1834\text{–}35, & 7\cdot999\ 976\ 4\,m & \text{at } 0^\circ C. \\ 1844\text{–}45, & 7\cdot999\ 871\ 6\,m^* & \text{at } 0^\circ C. \\ & \pm \qquad 5\ 5 & \end{array}$$

which last value was adopted by the observers and verified by Assistant J. E. Hilgard on July 11, 1854, and was to be used for the Kent Island as well as for the Massachusetts base measured in the same year. The coefficient of expansion of the bars was determined by Superintendent Hassler in 1817 at Newark,† the value found by him was 0·000 006 963 534 for the Fahrenheit scale, or 0·000 012 534 for the centigrade scale. This value has been supposed to be rather large, yet it may be correct for these particular bars and has been taken so by all previous investigators.‡ We shall, however, increase the probable error of the length of the base by the effect of a change in the adopted coefficient of expansion amounting to its $\frac{1}{10}$ part, which amount is supposed to cover the whole uncertainty.

We find for the length of the base:

	Metres.
1086 boxes of 8 metres each	8688·0000
Defect of each box on 8 metres, 1086 × 0·000 128 35	−0·1394
Correction for excess (25°·44 C.) of temperature of bars above 0° C. and graduation error of thermometers (−0°·255 C.)	+2·7424
Correction for inclination of boxes	−1·0007
Excess of box at south end, as measured by bar D and scale	−2·0508
Reduction to half tide level of bay, for surface elevation and height of box 5·0 m	−0·0069
Resulting length of base	8687·5446

The probable error of this value can only be estimated, since the base was measured but once. Supposing the combined length of the metres subject to $\pm 20\mu$, the effect on the base will be ±0·022 metre; an assumed error of $\pm\frac{1}{10}$ part in the expansion coefficient would produce ± 0·055 metre; again, the effect for imperfect temperature correction for inequality in number of boxes laid with rising and with falling temperature may be taken as ± 0·034 metre, while other minor uncertainties may be omitted. Combining the several values for probable error, we get ±0·068 metre, equal to $\frac{1}{127800}$ of the length nearly. This may be taken to represent the measuring error, and to include the probable error due to our practical unit of length, the Committee Metre, taken as $\pm \frac{3}{4}\mu$.

Resulting length of the Kent Island Base 8687·5446 metres,
± ·0680

and its logarithm 3·938 897 05.
± 3 40

*Coast Survey Report for 1865, Appendix No. 21, pp. 187, 188, and 189, and Coast Survey Report for 1866, Supplement to Appendix No. 8; Length of the Kent Island Base, p. 140.

† Trans. Amer. Phil. Soc., Vol. I, new series. Philadelphia, 1818, pp. 210–224.

‡ In connection with this it may be worth remarking that the coefficient of expansion for the 82-inch Troughton brass scale, which was determined by Mr. Hassler at the same time and by the same means, also was found rather large, viz: 0·000 010 509 for Fahrenheit's scale, or 0·000 018 916 for the centigrade scale. On the other hand, we have Fizeau's determination for our brass 0.000 018 410, yet brasses probably differ even more than different kinds of iron. A search was made for the recovery of the four Hassler bars, but without success.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS OBSERVED AND ADJUSTED AT STATIONS FORMING THE KENT ISLAND BASE NET, 1844, 1846–47–48–49–50, 1868 AND 1896–97.

Kent Island South Base, Queen Anne County, Maryland. May 30 to June 4, 1847. 30-centimetre repeating theodolite, No. 11. E. Blunt, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
1	Marriott	0 00 00·00	+0·03	00·03
2	Taylor	58 53 46·24	+0·06	46·30
3	Kent Island North Base	111 41 18·25	−0·09	18·16
	Poplar Island	283 38 46·74		

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ±0″·69.

Kent Island North Base, Queen Anne County, Maryland. May 21 to May 28, 1847. 30-centimetre theodolite, No. 11. E. Blunt, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
4	Kent Island South Base	0 00 00·00	+0·19	00·19
5	Marriott	50 05 05·36	−0·47	04·89
6	Taylor	88 35 36·91	−0·12	36·79
7	Linstid	121 02 04·33	+0·16	04·49
8	Swan Point	181 09 45·47	+0·24	45·71

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ±0″·68.

Swan Point, Kent County, Maryland. October 16 to October 21, 1848. 30-centimetre theodolite, No. 11. E. Blunt, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
34	Kent Island North Base	0 00 00·00	−0·23	$\overline{59{\cdot}77}$
35	Linstid	56 08 57·92	+0·52	58·44
36	Pooles Island	169 16 25·51	−0·29	25·22

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ±1″·35.

Taylor, Anne Arundel County, Maryland. June 8 to June 16, 1847. 30-centimetre theodolite, No. 11. E. Blunt, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
10	Kent Island North Base	0 00 00·00	+0·36	00·36
11	Kent Island South Base	38 36 52·37	−0·23	52·14
12	Marriott	119 32 44·32	+0·53	44·85
9	Linstid	247 12 54·29	−0·66	53·63

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ±0″·66.

Pooles Island, Harford County, Maryland. May 17 to May 27, 1848. 30-centimetre theodolite, No. 11. E. Blunt, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
31	Swan Point	0 00 00·00	+0·30	00·30
32	Linstid	36 22 15·13	+0·17	15·30
33	Finlay	116 06 54·92	−0·47	54·45
	Osborne's Ruin	170 34 06·56		
	Turkey Point	225 05 01·56		

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ±0″·69.

Webb, Anne Arundel County, Maryland. July 10 to August 14, 1848. 60-centimetre theodolite, No. 2. A. D. Bache, observer. October 21 to December 2, 1850. 75-centimetre theodolite, No. 1, A. D. Bache, observer. September 18 to September 25, 1868. 75-centimetre theodolite, No. 1, C. O. Boutelle, observer.

		°	°	″	″	″
26	Linstid	0	00	00·00	−0·02	59·98
27	Marriott	76	16	06·19	+0·25	06·44
	Hill	129	26	58·53		
	Soper	178	32	04·72		
	Stabler	186	55	11·56		
	Azimuth Mark	275	40	01·37		
25	Finlay	289	44	43·01	−0·23	42·78

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·94.

Marriott, Anne Arundel County, Maryland. November 18 to December 9, 1846. 30-centimetre theodolite, No. 11. E. Blunt, observer. May 18 to June 18, 1849. 60-centimetre theodolite, No. 2. A. D. Bache, observer.

		°	′	″	″	″
	Hill	0	00	00·00		
	Soper	32	06	10·36		
13	Webb	70	08	37·17	−0·24	36.93
	Azimuth mark	82	23	48·68		
14	Linstid	107	33	48·30	+0·34	48·64
15	Taylor	125	56	32·84	−0·20	32·64
16	Kent Island North Base	147	53	16·80	−0·10	16·70
17	Kent Island South Base	166	06	54·12	+0·19	54·31
	Poplar Island	206	58	03·32		
	Blake	248	21	51·62		

Probable error of a single observation of a direction— (6 *D.* and 6 *R.*) = ±0″·67 in 1846
(*D.* and *R.*) = ±1·10 in 1849

Linstid, Anne Arundel County, Maryland. May 24 to June 26, 1848. 60-centimetre theodolite, No. 2. A. D. Bache, observer. January 8 to January 31, 1897. 30-centimetre theodolite, No. 16. F. W. Perkins and W. B. Fairfield, observers. Telescope above ground (in 1897) 27·89 metres.

		°	′	″	″	″
18	Finlay	0	00	00·00	+0·70	00·70
19	Pooles Island	46	42	57·73	−0·18	57·55
	Clough	69	13	07·73		
20	Swan Point	77	13	16·97	−0·52	16·45
	Hope	102	07	23·10		
21	Kent Island North Base	140	56	37·60	−0·26	37·34
22	Taylor	175	43	02·43	+0·75	03·18
23	Marriott	209	40	11·28	−0·50	10·78
24	Webb	275	58	53·59	+0·02	9 53·61

Probable error of a single observation of a direction— (*D.* and *R.*) = ±1″·12 in 1848
(6 *D.* and 6 *R.*) = ±0·73 in 1897

Finlay, Baltimore County, Maryland. August 29 to September 11, 1844. 60-centimetre theodolite, No. 2. J. Ferguson, observer. October 15 to December 27, 1896. 30-centimetre theodolite, No. 16. G. A. Fairfield, observer. Telescope above ground 1·5 metres.

		°	′	″	″	″
	Osborne's Ruin	0	00	00·00		
	Still Pond	30	48	41·95		
28	Pooles Island	48	03	34·15	+0·48	34·63
	Clough	55	23	20·93		
29	Linstid	101	36	01·26	−0·72	00·54
30	Webb	127	19	37·46	+0·25	37·71
	Rosanne	159	25	03·26		

Probable error of a single observation of a direction— (*D.* and *R.*) $= \pm 1''{\cdot}52$ in 1844
(6 *D.* and 6 *R.*) $\pm 0''{\cdot}65$ in 1896

FIGURE ADJUSTMENT.

*Observation equations.**

No.	
1	$0 = +1{\cdot}05 - (2) + (3) - (4) + (6) - (10) + (11)$
2	$0 = -0{\cdot}62 - (5) + (6) - (10) + (12) - (15) + (16)$
3	$0 = +0{\cdot}49 - (1) + (3) - (4) + (5) - (16) + (17)$
4	$0 = -2{\cdot}31 - (6) + (7) - (9) + (10) - (21) + (22)$
5	$0 = +2{\cdot}97 + (9) - (12) - (14) + (15) - (22) + (23)$
6	$0 = -1{\cdot}37 - (13) + (14) - (23) + (24) - (26) + (27)$
7	$0 = -1{\cdot}87 + (18) - (24) - (25) + (26) - (29) + (30)$
8	$0 = +2{\cdot}73 - (18) + (19) - (28) + (29) - (32) + (33)$
9	$0 = +1{\cdot}26 - (19) + (20) - (31) + (32) - (35) + (36)$
10	$0 = -1{\cdot}07 - (7) + (8) - (20) + (21) - (34) + (35)$
11	$0 = -39 + 17{\cdot}1(4) - 17{\cdot}6(5) + 0{\cdot}5(6) + 26{\cdot}4(10) - 29{\cdot}8(11) + 3{\cdot}4(12) + 24{\cdot}9(15) - 63{\cdot}9(16) + 39{\cdot}0(17)$
12	$0 = +31 + 26{\cdot}4(5) - 59{\cdot}5(6) + 33{\cdot}1(7) + 63{\cdot}4(14) - 115{\cdot}6(15) + 52{\cdot}2(16) + 30{\cdot}3(21) - 61{\cdot}6(22) + 31{\cdot}3(23)$
13	$0 = -28 + 7{\cdot}3(5) - 19{\cdot}4(7) + 12{\cdot}1(8) + 27{\cdot}5(13) - 52{\cdot}3(14) + 24{\cdot}8(16) + 7{\cdot}6(25) - 12{\cdot}7(26) + 5{\cdot}1(27) + 15{\cdot}5(28) - 59{\cdot}2(29) + 43{\cdot}7(30) + 28{\cdot}6(31) - 32{\cdot}4(32) + 3{\cdot}8(33) + 14{\cdot}2(34) - 5{\cdot}2(35) - 9{\cdot}0(36)$

Correlate equations.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
(1)			−1										
(2)	−1												
(3)	+1		+1										
(4)	−1		−1								+17·1		
(5)	....	−1	+1	....	....	....	....	....	....	....	−17·6	+ 26·4	+ 7·3
(6)	+1	+1		−1							+ 0·5	− 59·5	
(7)				+1						−1		+ 33·1	−19·4
(8)										+1			+12·1
(9)				− 1	+1								

* Number of equations relating to sums of angles 10, and to ratio of sides 3, total number 13; the side equations were established with 7 places of decimals in the logarithms and the differences for 1″ are given in units of that place.

FIGURE ADJUSTMENT—continued.

Correlate equations—Continued.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
(10)	−1	−1	....	+1	....	....	....	....	....	....	+26·4	....	....
(11)	+1										−29·8		
(12)		+1			−1						+ 3·4		
(13)						−1							+27·5
(14)					−1	+1						+ 63·4	−52·3
(15)	....	−1	....	....	+1	....	....	....	....	....	+24·9	−115·6	....
(16)		+1	−1								−63·9	+ 52·2	+24·8
(17)			+1								+39·0		
(18)							+1	−1					
(19)								+1	−1				
(20)	....	....	....	....	....	....	....	....	+1	−1	....	....	....
(21)				−1						+1		+ 30·3	
(22)				+1	−1							− 61·6	
(23)					+1	−1						+ 31·3	
(24)						+1	−1						
(25)	....	....	....	....	....	....	−1	....	....	....	....	....	+ 7·6
(26)						−1	+1						−12·7
(27)						+1							+ 5·1
(28)								−1					+15·5
(29)							−1	+1					−95·2
(30)	....	....	....	....	....	....	+1	....	....	....	....	....	+43·7
(31)									−1				+28·6
(32)								−1	+1				−32·4
(33)								+1					+ 3·8
(34)										−1			+14·2
(35)	....	....	....	....	....	....	....	....	−1	+1	....	....	− 5·2
(36)									+1				− 9·0

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
0 = + 1·05	+6	+2	+2	−2							−72·8	−59·5	
− 0·62		+6	−2	−2	−2						−93·7	+81·9	+17·5
+ 0·49			+6								+68·2	−25·8	−17·5
− 2·31				+6	−2					−2	+25·9	+ 0·7	−19·4
+ 2·97					+6	−2					+21·5	−86·1	+52·3
− 1·37						+6	−2					+32·1	−62·0
− 1·87							+6	−2					+82·6
+ 2·73								+6	−2				−38·5
+ 1·26									+6	−2			−64·8
− 1·07										+6		− 2·8	+12·1
− 39											+8 423·2	− 6 708·4	− 1 713·2
+ 31												+31 132·9	− 2 470·7
− 28													+12 774·1

Resulting values of correlates and of corrections to angular directions.

Correlates	Corrections. ″	″	″
$C_1 = -0.059\ 67$	(1) = +0.031 0	(13) = −0.239 4	(25) = −0.230 1
C_2 +0.305 45	(2) = +0.059 7	(14) = +0.341 1	(26) = −0.021 3
C_3 −0.031 00	(3) = −0.090 7	(15) = −0.195 4	(27) = +0.251 4
C_4 +0.452 80	(4) = +0.189 7	(16) = −0.101 2	(28) = +0.475 8
C_5 −0.204 00	(5) = −0.471 6	(17) = +0.194 8	(29) = −0.724 7
C_6 +0.249 54	(6) = −0.116 7	(18) = +0.703 0	(30) = +0.249 0
C_7 +0.232 93	(7) = +0.164 2	(19) = −0.184 9	(31) = +0.295 7
C_8 −0.470 07	(8) = +0.237 3	(20) = −0.518 0	(32) = +0.173 0
C_9 −0.285 20	(9) = −0.656 8	(21) = −0.264 5	(33) = −0.468 7
C_{10} +0.232 83	(10) = +0.359 9	(22) = +0.747 4	(34) = −0.227 6
C_{11} +0.005 79	(11) = −0.232 2	(23) = −0.499 6	(35) = +0.516 1
C_{12} −0.001 47	(12) = +0.529 1	(24) = +0.016 6	(36) = −0.288 5

Checks: Sum of + corrections 55.35 and $\Sigma pvv = +4.867$
Sum of − corrections 55.32 $\quad -\Sigma wC = +4.872$

Mean error of an observed *direction* (of unit weight) $m_1 = \sqrt{\frac{[pvv]}{n}} = \sqrt{\frac{4.870}{13}} = \pm 0''.61$ where

n = number of conditions.

Mean error of an *angle* $m_> = m_1\sqrt{2} = \pm 0''.87$ and probable error of the same $\pm 0''.59$.

TRIANGLES OF THE KENT ISLAND BASE NET, MARYLAND, 1844 TO 1897.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log s.	Distances in metres.
1	Taylor	38	36	52.37	−0.59	51.78	0.08	3.938 897 1	8 687.545
	Kent I. N. Base	88	35	36.91	−0.31	36.60	0.08	4.143 529 1	13 916.47
	Kent I. S. Base	52	47	32.01	−0.15	31.86	0.08	4.044 816 9	11 087.07
				01.29			0.24		
2	Marriott	21	56	43.96	+0.09	44.05	0.15	4.044 816 9	11 087.07
	Taylor	119	32	44.32	+0.17	44.49	0.15	4.411 765 6	25 808.67
	Kent I. N. Base	38	30	31.55	+0.36	31.91	0.15	4.266 498 4	18 471.34
				59.83			0.45		
3	Marriott	40	10	21.28	+0.39	21.67	0.21	4.143 529 1	13 916.47
	Taylor	80	55	51.95	+0.76	52.71	0.22	4.328 444 0	21 303.16
	Kent I. S. Base	58	53	46.24	+0.03	46.27	0.22	4.266 498 5	18 471.34
				59.47			0.65		
4	Marriott	18	13	37.32	+0.29	37.61	0.14	3.938 897 1	8 687.545
	Kent I. N. Base	50	05	05.36	−0.66	04.70	0.15	4.328 444 1	21 303.16
	Kent I. S. Base	111	41	18.25	−0.12	18.13	0.15	4.411 765 8	25 808.68
				00.93			0.44		
5	Linstid	34	46	24.83	+1.01	25.84	0.09	4.044 816 9	11 087.07
	Kent I. N. Base	32	26	27.42	+0.28	27.70	0.09	4.018 198 2	10 427.93
	Taylor	112	47	05.71	+1.02	06.73	0.09	4.253 398 1	17 922.48
				57.96			0.27		

TRIANGLES OF THE KENT ISLAND BASE NET, MARYLAND, 1844 TO 1897—continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log s.	Distances in metres.
		°	′	″	″	″	″		
6	Linstid	33	57	08 ·85	− 1 ·25	07 ·60	0 ·13	4 ·266 498 5	18 471 ·34
	Taylor	127	40	09 ·97	− 1 ·18	08 ·79	0 ·13	4 ·417 956 2	26 179 ·19
	Marriott	18	22	44 ·54	− 0 ·54	44 ·00	0 ·13	4 ·018 198 2	10 427 ·93
				03 ·36			0 ·39		
7	Linstid	68	43	33 ·68	− 0 ·24	33 ·44	0 ·37	4 ·411 765 7	25 808 ·67
	Kent I. N. Base	70	56	58 ·97	+ 0 ·64	59 ·61	0 ·37	4 ·417 956 2	26 179 ·19
	Marriott	40	19	28 ·50	− 0 ·44	28 ·06	0 ·37	4 ·253 398 2	17 922 ·48
				01 ·15			1 ·11		
8	Webb	76	16	06 ·19	+ 0 ·27	06 ·46	0 ·33	4 ·417 956 2	26 179 ·19
	Linstid	66	18	42 ·31	+ 0 ·52	42 ·83	0 ·33	4 ·392 324 7	24 678 ·84
	Marriott	37	25	11 ·13	+ 0 ·58	11 ·71	0 ·34	4 ·214 204 0	16 375 ·86
				59 ·63			1 ·00		
9	Finlay	25	43	36 ·20	+ 0 ·97	37 ·17	0 ·49	4 ·214 204 0	16 375 ·86
	Linstid	84	01	06 ·41	+ 0 ·69	07 ·10	0 ·49	4 ·574 261 9	37 519 ·92
	Webb	70	15	16 ·99	+ 0 ·21	17 ·20	0 ·49	4 ·550 316 3	35 507 ·19
				59 ·60			1 ·47		
10	Pooles Island	79	44	39 ·79	− 0 ·64	39 ·15	0 ·64	4 ·550 316 3	35 507 ·19
	Linstid	46	42	57 ·73	− 0 ·89	56 ·84	0 ·63	4 ·419 418 8	26 267 ·50
	Finlay	53	32	27 ·11	− 1 ·20	25 ·91	0 ·63	4 ·462 716 4	29 021 ·27
				04 ·63			1 ·90		
11	Swan Point	56	08	57 ·92	+ 0 ·74	58 ·66	0 ·25	4 ·253 398 2	17 922 ·48
	Kent I. N. Base	60	07	41 ·14	+ 0 ·07	41 ·21	0 ·25	4 ·272 151 1	18 713 ·33
	Linstid	63	43	20 ·63	+ 0 ·26	20 ·89	0 ·26	4 ·286 689 1	19 350 ·36
				59 ·69			0 ·76		
12	Swan Point	113	07	27 ·59	− 0 ·81	26 ·78	0 ·23	4 ·462 716 4	29 021 ·27
	Linstid	30	30	19 ·24	− 0 ·33	18 ·91	0 ·23	4 ·204 626 3	16 018 ·66
	Pooles Island	36	22	15 ·13	− 0 ·12	15 ·01	0 ·24	4 ·272 151 2	18 713 ·34
				01 ·96			0 ·70		

PROBABLE ERRORS.

Determination of the probable errors of the length of the sides common to both the net and the adjacent chains of triangulation.

For the side Finlay to Linstid, as adjusted, we make use of the expression—

$$\frac{\text{Finlay to Linstid}}{\text{Kent Id. Base}} = \frac{\sin(3-1)\sin(7-5)\sin(14-13)\sin(26-25)}{\sin(17-16)\sin(23-21)\sin(27-26)\sin(30-29)}$$

hence the function—

$$F = \log\sin(3-1) + \log\sin(7-5) + \log\sin(14-13) + \log\sin(26-25)$$
$$-\log\sin(17-16) - \log\sin(23-21) - \log\sin(27-26) - \log\sin(30-29)$$

Establishing and solving the transfer equations, we find the reciprocal of weight $\frac{1}{P} = 27{\cdot}23$, also the mean error m_F and the probable error r_F, both expressed in units of the sixth place of decimals in their logs., viz: $\pm 3{\cdot}18$ and $\pm 2{\cdot}15$ respectively; hence log. distance Finlay to Linstid $\underset{\pm 21}{4{\cdot}550\ 316\ 3}$ and the distance $\underset{\pm 0{\cdot}18}{35\ 507{\cdot}19}$ metres. The probable error is about $\frac{1}{197000}$ part of the length.

To this must be added the proportional error depending upon that of the base measure, or $\pm 0{\cdot}068 \times \frac{35\ 507}{8\ 687} = \pm 0{\cdot}278$ metre, hence—

Probable error of length of side Finlay to Linstid $\sqrt{(0{\cdot}18)^2 + (0{\cdot}278)^2} = \pm 0{\cdot}33$ metre.

For the side Webb to Marriott, we use the expression—

$$\frac{\text{Webb to Marriott}}{\text{Kent Island Base}} = \frac{\sin(24-23)\sin(7-5)\sin(3-1)}{\sin(27-26)\sin(23-21)\sin(17-16)}$$

$$F = \log\sin(24-23) + \log\sin(7-5) + \log\sin(3-1) - \log\sin(27-26) - \log\sin(23-21) - \log\sin(17-16)$$

Establishing and solving the transfer equations—

We get $\frac{1}{P} = 17{\cdot}91$, also $m_F = \pm 2{\cdot}58$ and $r_F = \pm 1{\cdot}74$, hence log. distance Webb to Marriott $\underset{\pm 1\ 7}{4{\cdot}392\ 324\ 7}$, and distance $= \underset{\pm 0{\cdot}10}{24\ 678{\cdot}84}$ metres. The probable error is about $\frac{1}{247000}$ part; adding to this the proportional error arising from the base measure or $0{\cdot}068 \times \frac{24\ 678}{8\ 687} = \pm 0{\cdot}193$ metre, we have

Probable error of length of side Webb to Marriott $\sqrt{(0{\cdot}10)^2 + (0{\cdot}193)^2} = \pm 0{\cdot}22$ metre.

DESCRIPTION OF STATIONS FORMING THE KENT ISLAND BASE NET, MARYLAND.

Kent Island North Base, Queen Anne County; established in 1844 by James Ferguson. The island is situated on the east side of Chesapeake Bay nearly opposite Annapolis Harbor. The station is located on the south side of Broad Creek, near its mouth, on the western shore of the island. The end of the base line was carefully marked, both by underground and surface monuments. It is reported by persons living in the vicinity in 1896 that the ground at this end of the base has been washed away.

Kent Island South Base, Queen Anne County; established in 1844 by James Ferguson. The station was situated near the extreme end of the point of land between Prices Creek and Chesapeake Bay, and was marked in a similar manner to North Base. A careful search for this point in 1888 proved that the ground had been washed into the bay years before.

Taylor, Anne Arundel County; established in 1844 by James Ferguson. The station is situated on the west side of Chesapeake Bay, on Greenburg Point, between Mill Creek and the Severn River. The geodetic point is on the most prominent spot on a hill, 91 feet above the level of the bay, belonging to Capt. Lemuel Taylor. It is about one-fourth mile from his house, on the north side of the road leading to the Severn Ferry. Its position was marked by three stakes, each 40 feet distant, one in the direction of "Marriott," another in the line to "Linstid," and the other one on that line extended southwardly. It is also 226 feet from a small chestnut tree toward the line to "Marriott." This point was searched for in 1859 and in 1888, but no trace of it could be found.

Swan Point, Kent County; established in 1842 by James Ferguson. This station was originally situated on a point of land on the north side of the mouth of Chester River, on the eastern shore of Chesapeake Bay. A resurvey of this shore in 1896 shows that the site of the original station is some distance out in the bay.

Marriott, Anne Arundel County; established in 1844 by James Ferguson. This station is situated about 20 miles east of Washington City, 6½ miles southwest of South River, and about 9¾ miles southwest of Annapolis. The geodetic point is on the property of B. Marriott, about 100 yards east of the road leading from Annapolis to St. Marys. It is 99 feet from the main post of an old windmill and 34 feet 11 inches from a small hut on the south side of the hill. Three stakes were driven into the ground, each 30 feet distant, one in the direction of "Taylor" and the other two at right angles to that line.

(No mention is made in the original description of either surface or underground marks, but I presume an earthenware cone was buried there, as seems to have been the custom at that time.—G. A. F.)

Webb, Anne Arundel County; established in 1846 by A. D. Bache. This station is situated about 12 miles northwest of Annapolis and about 2½ miles, by road, east of Odenton, the junction of the Baltimore and Potomac Railroad and the Annapolis branch of the Baltimore and Ohio Railroad. The land now (1896) belongs to James Woodward, president of the Hanover National Bank, New York City. The geodetic point is on a small hill covered with a thick growth of young trees about 45 feet high, and is marked as follows: The subsurface mark is the usual earthenware cone, the top 1·7 feet below the surface, and over this a small granite block, 7 inches square and 5 inches thick, the top 1·1 feet below the surface of the ground. The surface mark is a rough block of granite 1·2 feet long with a 4-inch square dressed on top and two shallow cross lines marking the center. As reference marks 3 granite posts—each 2 feet and 2 inches long and 5 inches square at the top, with diagonal lines cut on them—were set 5 feet distant from the geodetic point; one due north, one due south, and one due east.

Linstid, Anne Arundel County; established in 1844 by James Ferguson. This station is situated on the west side of Chesapeake Bay, on what is known as Eagle Hill, near the head of Broad Creek on the north shore of Magothy River. It is about one-half mile in a northerly direction from the old Linstid house and just east of the road which passes over the west side of the hill. The station was re-marked, in January, 1897, as follows: The underground mark is an earthenware cone 15 inches high, upper diameter 6·5 inches and lower diameter 12·5 inches; the center marking the station.

The top is 26 inches below the surface. About 2 feet north of the center and 9 inches below the surface a granite block (6 by 7 by 18 inches, with one end dressed to 5 inches square and diagonal cross lines on it), was laid horizontally, the dressed end toward the center. The surface mark is a rough granite block 18 inches long, the head dressed to 5 inches square with a hole one-half inch in diameter and three-eighths inch deep in the center; the top being even with the surface of the ground. The reference marks are triangular blazes cut in 2 chestnut trees, with sixtypenny nails driven in the center. One tree is 2·3 feet in diameter, bearing north 76°·5 east magnetic, and distant 48·87 feet, and the other 1·7 feet in diameter, bearing south 2°·7 east magnetic, and distant 17·31 feet from the station.

Finlay, Baltimore County; established in 1844 by James Ferguson. This station is situated on Cub Hill, about 9 miles from Baltimore on the old Harford road and about 5 miles east of Towson. It is located on the old Finlay farm—now (1896) the property of Mr. Theodore Fastie—about 300 feet east of the old Harford road and five-eighths of a mile west of the Harford turnpike. The geodetic point was re-marked in 1896 as follows: A glazed drain tile 4 inches in diameter and 30 inches long, filled with cement and gravel, was sunk in the ground so that the upper end was 3 feet below the surface. It was set in cement and gravel and a sixtypenny nail at the center of the tile marks the station. The surface mark is a chestnut post, the top being even with the surface of the ground and having a fortypenny nail in the center.

The northeast corner of an old log house—now used as a blacksmith shop—distant 253·71 feet, bears north 47° 06′ west (true); a large cherry tree, distant 126·85 feet, bears south 22° 46′ east (true), and the east gable of the stone barn on the Fastie place bears north 9° 27′ east (true) from the geodetic point.

Pooles Island, Harford County; established in 1844 by James Ferguson. Pooles Island is in Chesapeake Bay, near its head, about opposite the mouth of Gunpowder River. The geodetic point is located near the south end of the upper half of the island, about 450 feet in a northwesterly direction from the large dwelling house of Mr. John Masheter, present (1896) owner of the island.

A careful search was made for this point in 1896, but as all surface and reference marks, except one, had been destroyed many years before, the underground marks could not be found.

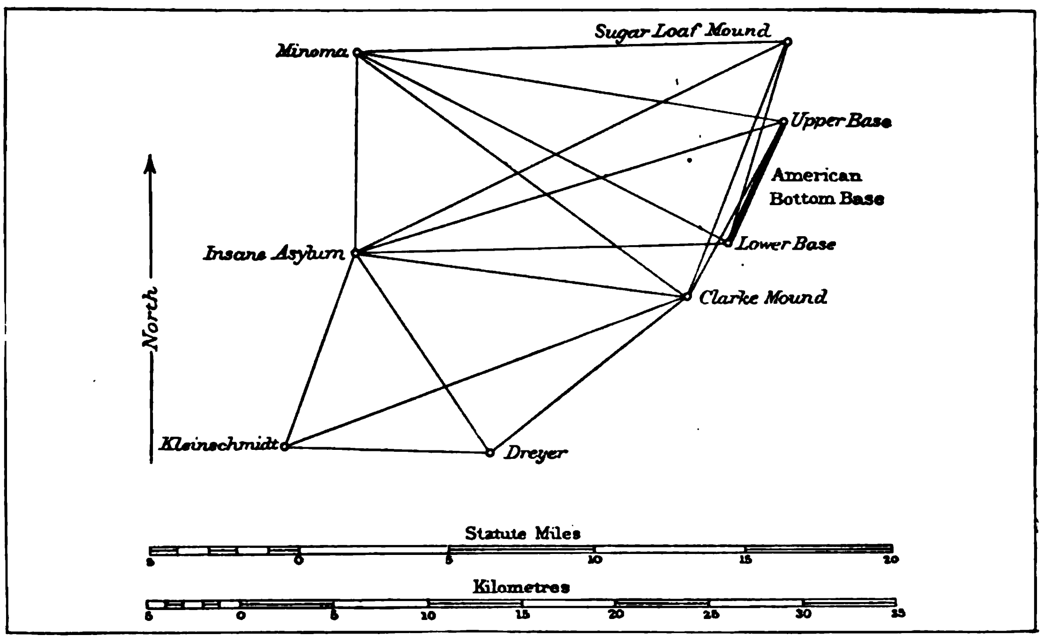
(*b*) *American Bottom Base Line, Illinois, 1872.*

LOCATION, MEASUREMENT, AND LENGTH.

This base is located in St. Clair and Madison counties, Illinois, in the bottom lands of the Mississippi River, on the eastern or Illinois side of it, and nearly opposite St. Louis, Missouri, and about 16 kilometres (10 statute miles) distant from it. It served, in the first instance, for a local survey about St. Louis. The two end points are upon spurs of bluffs about 15 metres (say 50 feet) or more elevated above the general level of the bottom lands. These elevations were desirable in order to have a clear line of sight over the forests that fringe the low lakes, ponds, and swamps which occupy the middle portion of the lowlands. The middle point of the base is in latitude 38° 38′·2 and in longitude 90° 02′·0, nearly; the azimuth of the lower or southern point, as seen from the northern end, is 24° 40′; the total length is 7·27 kilometres, or 4·52 statute

miles. The line lies for more than nine-tenths of its length over wheat and corn lands, crosses 3 main roads, 2 railroads, and 8 bridges over creeks and dry runs. The latter structures were of a simple kind, and designed only to support the measuring bars. The measurement was made with two 6-metre contact-slide rods, known as Nos. 1 and 2. A description of the apparatus, embodying the principle and construction of Colonel Mudge's apparatus, and as modified and improved, will be found in Appendix No. 17, Coast and Geodetic Survey Report for 1880, pp. 341–345. Only one measure was made, and the work was in charge of Assistant C. H. Boyd, aided by Assistant Van Orden and Mr. Featherson, civil engineer; it occupied the time between October 30 and November 11, 1872. A line of spirit levels was carried from the so-called City Directrix at St. Louis to the Lower Base Monument. The St. Louis bench mark is connected with the Gulf and Atlantic levels.

No. 4.



The Upper Base or northern terminus is marked by a limestone monument with marks above and below the ground; that on the monument is a cross cut in a copper bolt, while under the center and about 1·2 metres (4 feet) below ground is an earthenware pyramid. After these terminals had been built for about a month, the line was staked out at distances of 120 metres; during the measurement every twentieth bar was plumbed down and secured by a stake and copper tack; the bars were protected by a portable tent; their inclination was had from sector readings, which also gave the profile of the whole line. A thermometer was attached to each bar and recorded.

The 6-metre contact-slide rods, Nos. 1 and 2, were made at the Survey office in August, 1867. The last determination of their length before the measure of the American Bottom Base was in April and August, 1870, and was made by comparisons with the 6-metre standard bar No. 2. The length of this last bar, which dates back to

February, 1855, was determined in April, 1860, by Assistant J. E. Hilgard, with the result—

$$S_2 = 5.999\ 982\ 3 \text{ metres at } 0^\circ C.$$
$$\pm \quad 1\ 0$$

Its coefficient of expansion was not determined until March, 1897 (see Assistant A. Braid's report of March 27, 1897); it was found equal to 0.000 011 25 for the centigrade scale. The comparisons of S_2 with rods Nos. 1 and 2 were made by means of a Repsold lever comparator, of which 1 turn = 316.75 microns and 1 division = 3.168μ.

The comparisons of April 29, 1870, give—

$$S_2 - \text{No. 1 at } 60^\circ.3 \text{ F.} = +33^d.50 \quad \text{or} \quad \text{No. 1} = 6^m.001\ 149\ 5 \text{ at } 15^\circ.72 \text{ C.}$$
$$S_2 - \text{No. 2 at } 60^\circ.1 \text{ F.} = -35^d.17 \quad \text{or} \quad \text{No. 2} = 6^m.000\ 924\ 6 \text{ at } 15^\circ.61 \text{ C.}$$

The comparisons of August 30, 1870, give—

$$S_2 - \text{No. 1 at } 73^\circ.07 \text{ F.} = +31^d.40 \quad \text{or} \quad \text{No. 1} = 6^m.001\ 622\ 1 \text{ at } 22^\circ.82 \text{ C.}$$
$$S_2 - \text{No. 2 at } 72^\circ.90 \text{ F.} = -35^d.91 \quad \text{or} \quad \text{No. 2} = 6^m.001\ 402\ 1 \text{ at } 22^\circ.72 \text{ C.}$$

Hence we have—

Length of rod No. 1 at	19.27 C.	6.001 385 8 *m.*
Length of rod No. 2 at	19.16 C.	6.001 163 4 *m.*
Mean,	19.215	6.001 274 6

In the absence of other determinations for the coefficient of expansion of the rods Nos. 1 and 2 we deduce from the above comparison for—

$$\left.\begin{array}{ll}\text{No. 1} & \alpha = 11.10\mu \\ \text{No. 2} & 11.19\mu\end{array}\right\} \text{for the C. scale.}$$

For the elevation of the base above the mean sea level we have from the unadjusted (not yet completed) lines of spirit levels the height of the St. Louis City Directrix, transferred to the bridge across the Mississippi 125.8 ± 0.3 metres; also by spirit leveling in 1882 by Assistant A. Braid, top of monument (copper bolt) at Upper Base above the City Directrix 32.79 metres; hence the elevation of Upper Base is 158.6 metres; also by spirit leveling in November, 1872, by W. Bauer, top of monument at Lower Base above the City Directrix 21.67 metres, and elevation of Lower Base 147.5 metres. The difference in height of the base ends 11.1 metres is verified by the sector readings during the base measure. Whence we get the average elevation of the base above half tide level of the ocean 132.1 metres, to which is to be added 1.1 metres for height of apparatus above ground. The total elevation is therefore 133.2 metres; log radius of curvature 6.803 8.

With the above data the length of the American Bottom Base comes out as follows:

		Metres.
Length of 1 210 mean rods Nos. 1 and 2 at an average temperature of 58°.69 F. or 14°.828 C.		7 261.187 3
Length of rod No. 1 at 15°.0 C	+	6.001 7
Excess of Lower Base mark over the last bar laid	+	0.856 9
Correction for inclination	−	1.010 1
Reduction to sea level	−	0.152 1
Resulting length of base		7 266.883 7

As the base was measured but once, the accuracy of the result can only be roughly estimated. To the mere comparing error ($\pm 1{\cdot}0\mu$) of S_2 we add $\pm 6\mu$—that is, 1 micron for each metre—hence probable error for base or 1 211 bars, $\pm 7{\cdot}4$ millimetres. The temperature of the rods may be uncertain by $\pm 0^\circ{\cdot}2$ C, considering that there was but one thermometer attached to a rod; the effect of this upon the length of the base is $\pm 16{\cdot}2$ millimetres. A probable error of 0·5 metre in the adopted elevation of the base would produce $\pm 0{\cdot}6$ millimetre. Taking the probable error of a single measure of a kilometre to be $\pm 1{\cdot}2$ millimetres (Salina Base), that of the base becomes $\pm 8{\cdot}7$ millimetres. Combining these four probable errors we get $\pm 19{\cdot}9$ millimetres or $\frac{1}{365\,000}$ of the length. This may be taken to represent the measuring error; combining it with the probable error due to our practical unit of length, the Committee Metre, taken as $\pm \frac{3}{4}\mu$, we get $\sqrt{(19{\cdot}9)^2 + (5{\cdot}4)^2} = \pm 20{\cdot}6$ millimetres or about $\frac{1}{353\,000}$ part of the length.

Final result for length of base 7 266·883 7 metres,
$\pm$ 20 6

and logarithm of its length 3·861 348 21
$\pm$ 1 23

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE AMERICAN BOTTOM BASE NET, 1871–72–73 AND 1880.

American Bottom Lower Base, St. Clair County, Illinois. November 12 to November 13, 1872. 25-centimetre theodolite, No. 92. C. H. Van Orden, observer. May 24 to May 28, 1873. 28-centimetre theodolite, No. 100. C. H. Boyd, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″
1	Insane Asylum	0	00	00·00	+0·33	00·33
2	Minoma	28	06	02·46	+0·31	02·77
	Standpipe	28	14	37·11		
3	Sugar Loaf Mound	109	16	57·79	−0·81	56·98
4	American Bottom Upper Base	114	45	13·03	+0·17	13·20

Probable error of a single observation of a direction ($3D$. and $3R$.) $= \pm 1''{\cdot}14$.

American Bottom Upper Base, Madison County, Illinois. October 24 to November 13, 1872. 25-centimetre theodolite, No. 74. C. H. Boyd, observer. May 8 to May 23, 1873. 28-centimetre theodolite, No. 100. C. H. Boyd, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″
5	American Bottom Lower Base	0	00	00·00	+0·17	00·17
6	Clarks Mound	2	04	23·41	+0·57	23·98
7	Insane Asylum	49	10	58·48	+0·62	59·10
	Standpipe	67	51	38·28		
8	Minoma	75	09	13·58	−1·36	12·22

Probable error of a single observation of a direction ($3D$. and $3R$.) $= \pm 1''{\cdot}19$.

Dreyer, St. Clair County, Illinois. October 26 to October 27, 1871. 30-centimetre theodolite, No. 32. R. E. Halter, O. H. Tittmann, observers. June 20, 1873. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer. November 19 to December 1, 1880. 30-centimetre theodolite, No. 107. G. A. Fairfield, observer. Telescope above ground 10·21 metres in 1880.

		°	′	″	″	″
31	Kleinschmidt	0	00	00·00	+0·77	00·77
32	Insane Asylum	56	04	42·32	−1·40	40·92
	Standpipe	85	08	41·16		
33	Clarks Mound	140	08	32·76	+0·63	33·39
	Turkey Hill	184	06	27·79		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·98.

Clarks Mound, St. Clair County, Illinois. October 13 to November 10, 1871. 30-centimetre theodolite, No. 32. R. E. Halter, O. H. Tittman, observers. May 28 to May 31, 1873. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer. August 13 to September 4, 1880. 30-centimetre theodolite, No. 107. G. A. Fairfield, observer. Telescope above ground 10·06 metres in 1880.

		°	′	″	″	″
25	Dreyer	0	00	00·00	+0·39	00·39
26	Kleinschmidt	17	23	30·35	−1·80	28·55
27	Insane Asylum	46	08	58·34	+0·75	59·09
28	Minoma	73	51	07·94	+0·73	08·67
	Standpipe	77	38	29·97		
29	Sugar Loaf Mound	149	26	05·45	+0·95	06·40
30	American Bottom Upper Base	154	17	03·14	−1·02	02·12
	Berger	210	04	34·22		
	Turkey Hill	256	01	11·05		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·39 *C.*

Sugar Loaf Mound, Madison County, Illinois. May 12 to May 24, 1873. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer. September 13 to September 24, 1880. 30-centimetre theodolite, No. 107. G. A. Fairfield, observer. Telescope above ground, 14·20 meters in 1880.

		°	′	″	″	″
	Parkinson	0	00	00·00		
	Berger	30	24	26·70		
21	American Bottom Lower Base	114	53	21·82	+0·09	21·91
22	Clarks Mound	117	35	06·48	−0·24	06·24
23	Insane Asylum	161	07	27·22	−0·33	26·89
	Standpipe	174	35	29·21		
24	Minoma	185	11	47·19	+0·48	47·67

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·20.

Insane Asylum, St. Louis County, Missouri. November 8 to November 10, 1871. 30-centimetre theodolite, No. 14. W. Eimbeck, observer. October 2 to October 12, 1872. 25-centimetre theodolite, No. 92. C. H. Van Orden, observer. June 5 to June 23, 1873. 28-centimeter theodolite, No. 100. C. H. Boyd and C. H. Van Orden, observers.

		°	′	″	″	″
14	Minoma	0	00	00·00	−0·27	59·73
	Standpipe	39	46	44·35		
15	Sugar Loaf Mound	65	21	06·63	+1·27	07·90
16	American Bottom Upper Base	73	46	19·17	− ·88	18·29
17	American Bottom Lower Base	89	50	07·81	−1·00	06·81
18	Clarks Mound	98	31	40·32	+ ·29	40·61
19	Dreyer	148	18	49·26	+ ·66	49·92
20	Kleinschmidt	200	16	12·64	− ·07	12.57
	Patterson	235	18	46·97		
	Kessler	271	34	38·11		
	Morgan	306	29	30·88		

Probable error of a single observation of a direction (3*D*. and 3*R*.) = ± 1″·30.

Kleinschmidt, St. Louis County, Missouri. November 21 to December 9, 1871. 30-centimetre theodolite, No. 32. W. Eimbeck, observer. June 21 to June 22, 1873. - 25-centimetre theodolite, No. 74. C. H. Van Orden, observer.

		°	′	″	″	″
	Patterson	0	00	00·00		
	Morgan	85	05	58·51		
34	Insane Asylum	124	05	37·73	+0·58	38·31
	Azimuth Mark	124	37	35·99		
	Standpipe	132	54	24·14		
35	Clarks Mound	173	35	37·11	−0·76	36·35
36	Dreyer	196	03	35·63	+0·19	35·82

Probable error of a single observation of a direction (3*D*. and 3*R*.) = ± 0″·90.

Minoma, St. Louis County, Missouri. June 5 to June 11, 1873. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer.

		°	′	″	″	″
9	Sugar Loaf Mound	0	00	00·00	−1·20	58·80
10	American Bottom Upper Base	10	18	59·95	+1·60	61·55
	Standpipe	28	11	26·91		
11	American Bottom Lower Base	28	30	38·95	+0·52	39·47
12	Clarks Mound	36	48	21·53	−1·08	20·45
13	Insane Asylum	90	34	30·33	+0·16	30·49
	Morgan	164	32	12·93		

Probable error of a single observation of a direction (3*D*. and 3*R*.) = ± 0″·84.

FIGURE ADJUSTMENT.

*Observation equations.**

No.	
1	$0 = +2{\cdot}74 + (11) - (10) + (8) - (5) + (4) - (2)$
2	$0 = +1{\cdot}11 + (17) - (14) + (13) - (11) + (2) - (1)$
3	$0 = +3{\cdot}83 + (23) - (21) + (3) - (1) + (17) - (15)$
4	$0 = -3{\cdot}71 + (13) - (9) + (24) - (23) + (15) - (14)$
5	$0 = +0{\cdot}55 + (30) - (27) + (18) - (16) + (7) - (6)$
6	$0 = +6{\cdot}36 + (30) - (28) + (12) - (10) + (8) - (6)$
7	$0 = -1{\cdot}77 + (28) - (27) + (18) - (14) + (13) - (12)$
8	$0 = -1{\cdot}06 + (29) - (28) + (12) - (9) + (24) - (22)$
9	$0 = -2{\cdot}76 + (33) - (32) + (19) - (18) + (27) - (25)$
10	$0 = +3{\cdot}29 + (36) - (34) + (20) - (19) + (32) - (31)$
11	$0 = +1{\cdot}38 + (33) - (31) + (36) - (35) + (26) - (25)$
12	$0 = +4{\cdot}0 - 1{\cdot}26(5) + 1{\cdot}82(7) - 0{\cdot}56(8) - 6{\cdot}40(10) + 7{\cdot}52(11) - 1{\cdot}12(13) + 7{\cdot}31(16) - 7{\cdot}31(17)$
13	$0 = +5{\cdot}3 - 4{\cdot}68(1) + 3{\cdot}94(2) + 0{\cdot}74(3) + 0{\cdot}02(9) + 1{\cdot}12(11) - 1{\cdot}14(13) - 2{\cdot}02(21) + 6{\cdot}74(23) - 4{\cdot}72(24)$
14	$0 = +17{\cdot}4 - 1{\cdot}31(6) + 1{\cdot}95(7) - 0{\cdot}64(8) - 4{\cdot}22(10) + 5{\cdot}77(12) - 1{\cdot}55(13) + 0{\cdot}31(14) + 4{\cdot}57(16) - 4{\cdot}88(18)$
15	$0 = -0{\cdot}6 - 2{\cdot}82(9) + 4{\cdot}37(12) - 1{\cdot}55(13) + 0{\cdot}31(14) + 3{\cdot}22(15) - 3{\cdot}53(18) - 1{\cdot}35(22) + 2{\cdot}22(23) - 0{\cdot}87(24)$
16	$0 = +18{\cdot}7 - 1{\cdot}78(18) + 3{\cdot}43(19) - 1{\cdot}65(20) - 4{\cdot}70(25) + 6{\cdot}72(26) - 2{\cdot}02(27) - 0{\cdot}68(34) + 5{\cdot}09(35) - 4{\cdot}41(36)$

Correlate equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
(1)		−1	−1										−4·68			
(2)	−1	+1											+3·94			
(3)			+1										+0·74			
(4)	+1															
(5)	−1	....	...	....	....	....	....	....	....	....	....	−1·26	....	....	....	....
(6)					−1	−1								−1·31		
(7)					+1							+1·82		+1·95		
(8)	+1					+1						−0·56		−0·64		
(9)				−1				−1					+0·02		−2·82	
(10)	−1	....	....	....	....	−1	....	....	....	....	....	−6·40	.. .	−4·22	....	....
(11)	+1	−1										+7·52	+1·12			
(12)						+1	−1	+1						+5·77	+4·37	
(13)		+1		+1			+1					−1·12	−1·14	−1·55	−1·55	
(14)		−1		−1			−1							+0·31	+0·31	
(15)	....	....	−1	+1	....	....	....	....	....	....	....	....	....	....	+3·22	....
(16)					−1							+7·31		+4·57		
(17)		+1	+1									−7·31				
(18)					+1		+1		−1					−4·88	−3·53	−1·78
(19)									+1	−1						+3·43
(20)	....	....	....	....	....	....	....	....	....	+1	....	....	....	....	....	−1·65
(21)			−1										−2·02			
(22)								−1							−1·35	
(23)			+1	−1									+6·74		+2·22	
(24)				+1				+1					−4·72		−0·87	
(25)	....	....	....	....	....	....	....	....	−1	....	−1	....	....	....	....	−4·70
(26)											+1					+6·72
(27)					−1		−1		+1							−2·02
(28)						−1	+1	−1								

* Number of angle equations 11 and of side equations 5; the latter are established with 7 place logarithms, differences for 1″ refer to the sixth place of decimals.

FIGURE ADJUSTMENT—continued.

Correlate equations—Continued.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
(29)								+1								
(30)	....	....	....	....	+1	+1	....	....	....	....	....	....	....	....	....	....
(31)										−1	−1					
(32)									−1	+1						
(33)									+1		+1					
(34)										−1						−0·68
(35)	....	....	....	....	....	....	....	....	....	....	−1	....	....	....	....	+5·09
(36)										+1	+1					−4·41

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
0=+ 2·74	+6	−2				+2						+ 14·62	− 2·82	+ 3·58		
+ 1·11		+6	+2	+2			+2					− 15·95	+ 6·36	− 1·86	− 1·86	
+ 3·83			+6	−2								− 7·31	+ 14·18		− 1·00	
− 3·71				+6			+2	+2				− 1·12	− 12·62	− 1·86	+ 1·09	
+ 0·55	....	....	....	....	+6	+2	+2	....	−2	....	....	− 5·49	....	− 6·19	− 3·53	+ 0·24
+ 6·36						+6	−2	+2				+ 5·84		+ 10·66	+ 4·37	
− 1·77							+6	−2	−2			− 1·12	− 1·14	− 12·51	− 9·76	+ 0·24
− 1·06								+6					− 4·74	+ 5·77	+ 7·67	
− 2·76									+6	−2	+2			+ 4·88	+ 3·53	+ 7·89
+ 3·29	....	....	....	....	....	....	....	....	....	+6	+2	....	....	....	....	− 8·81
+ 1·38											+6					+ 1·92
+ 4·0												+210·85	+ 9·71	+ 66·06	+ 1·74	
+ 5·3													+112·31	+ 1·77	+20·78	
+17·4														+104·23	+44·94	+ 8·69
− 0·6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+59·88	+ 6·28
+18·7																+134·80

Resulting values of correlates and of corrections to angular directions.

Correlates		
C_1 = +0·174		
C_2 −1·742		
C_3 −1·229		
C_4 +1·742		
C_5 +0·453		
C_6 −1·470		
C_7 +0·208		
C_8 +0·950		
C_9 +0·972		
C_{10} −0·429		
C_{11} −0·342		
C_{12} −0·270		
C_{13} +0·565		
C_{14} +0·338		
C_{15} −0·527		
C_{16} −0·217		

Corrections.

″	″	″
(1) = +0·327	(13) = +0·159	(25) = +0·390
(2) + ·310	(14) − ·266	(26) −1·800
(3) − ·811	(15) +1·274	(27) + ·749
(4) + ·174	(16) − ·882	(28) + ·728
(5) + ·166	(17) − ·997	(29) + ·950
(6) + ·574	(18) + ·286	(30) −1·017
(7) + ·621	(19) + ·657	(31) + ·771
(8) −1·361	(20) − ·071	(32) −1·401
(9) −1·195	(21) + ·088	(33) + ·630
(10) +1·598	(22) − ·239	(34) + ·577
(11) +0·519	(23) − ·333	(35) − ·763
(12) −1·081	(24) + ·483	(36) + ·186

Checks: Sum of all + corrections 12·217 and $\Sigma pvv = +23{\cdot}648$
Sum of all − corrections 12·217 and $-\Sigma wC = +23{\cdot}615$

Mean error of an observed *direction* $m_1 = \sqrt{\frac{[pvv]}{n}} = \pm 1''{\cdot}22$

where n = number of conditions.

Mean error of an *angle* $m_{\angle} = m_1\sqrt{2} = \pm 1''{\cdot}72$ and probable error of same $\pm 1''{\cdot}16$.

TRIANGLES OF THE AMERICAN BOTTOM BASE NET, ILLINOIS AND MISSOURI, 1871 to 1880.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
1	Minoma	18	11	39·00	−1·08	37·92	0·14	3·861 348 2	7 266·884
	Am. Bot. Up. Base	75	09	13·58	−1·53	12·05	0·14	4·352 123 5	22 496·94
	Am. Bot. Low. Base	86	39	10·57	−0·13	10·44	0·13	4·366 128 5	23 234·24
				03·15			0·41		
2	Insane Asylum	73	46	19·17	−0·61	18·56	0·21	4·366 128 5	23 234·24
	Minoma	80	15	30·38	−1·44	28·94	0·20	4·377 478 4	23 849·45
	Am. Bot. Up. Base	25	58	15·10	−1·98	13·12	0·21	4·025 166 1	10 596·59
				04·65			0·62		
3	Insane Asylum	89	50	07·81	−0·73	07·08	0·18	4·352 123 5	22 496·94
	Minoma	62	03	51·38	−0·36	51·02	0·18	4·298 318 3	19 875·51
	Am. Bot. Low. Base	28	06	02·46	−0·02	02·44	0·18	4·025 166 1	10 596·59
				01·65			0·54		
4	Insane Asylum	16	03	48·64	−0·12	48·52	0·11	3·861 348 2	7 266·884
	Am. Bot. Up. Base	49	10	58·48	+0·45	58·93	0·11	4·298 318 3	19 875·51
	Am. Bot. Low. Base	114	45	13·03	−0·15	12·88	0·11	4·377 478 3	23 849·45
				00·15			0·33		
5	Sugar Loaf Mound	46	14	05·40	−0·42	04·98	0·18	4·298 318 3	19 875·51
	Am. Bot. Low. Base	109	16	57·79	−1·14	56·65	0·18	4·414 600 7	25 977·70
	Insane Asylum	24	28	61·18	−2·27	58·91	0·18	4·057 117 2	11 405·57
				04·37			0·54		
6	Sugar Loaf Mound	70	18	25·37	+0·40	25·77	0·21	4·352 123 5	22 496·94
	Am. Bot. Low. Base	81	10	55·33	−1·12	54·21	0·22	4·373 133 3	23 612·03
	Minoma	28	30	38·95	+1·71	40·66	0·21	4·057 117 2	11 405·57
				59·65			0·64		
7	Sugar Loaf Mound	24	04	19·97	+0·82	20·79	0·21	4·025 166 1	10 596·59
	Insane Asylum	65	21	06·63	+1·54	08·17	0·21	4·373 133 2	23 612·02
	Minoma	90	34	30·33	+1·35	31·68	0·22	4·414 600 7	25 977·70
				56·93			0·64		
8	Clarks Mound	27	42	09·60	−0·02	09·58	0·16	4·025 166 1	10 596·59
	Insane Asylum	98	31	40·32	+0·55	40·87	0·17	4·352 994 4	22 542·10
	Minoma	53	46	08·80	+1·24	10·04	0·16	4·264 505 3	18 386·76
				58·72			0·49		
9	Clarks Mound	103	17	07·11	+0·20	07·31	0·22	4·414 600 7	25 977·70
	Insane Asylum	33	10	33·69	−0·99	32·70	0·22	4·164 534 3	14 606·10
	Sugar Loaf Mound	43	32	20·74	−0·09	20·65	0·22	4·264 505 3	18 386·76
				01·54			0·66		
10	Clarks Mound	108	08	04·80	−1·77	03·03	0·15	4·377 478 3	23 849·45
	Insane Asylum	24	45	21·15	+1·17	22·32	0·16	4·021 566 1	10 509·11
	Am. Bot. Up. Base	47	06	35·07	+0·05	35·12	0·16	4·264 505 2	18 386·76
				01·02			0·47		

TRIANGLES OF THE AMERICAN BOTTOM BASE NET, ILLINOIS AND MISSOURI, 1871 TO 1880—cont'd.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log s.	Distances in metres.
		°	′	″	″	″	″		
11	Clarks Mound	75	34	57·51	+0·22	57·73	0·27	4·373 133 3	23 612·03
	Minoma	36	48	21·53	+0·12	21·65	0·27	4·164 534 3	14 606·10
	Sugar Loaf, Md.	67	36	40·71	+0·72	41·43	0·27	4·352 994 4	22 542·10
				59·75			0·81		
12	Clarks Mound	80	25	55·20	−1·75	53·45	0·19	4·366 128 5	23 234·24
	Minona	26	29	21·58	−2·68	18·90	0·20	4·021 566 1	10 509·11
	Am. Bot. Up. Base	73	04	50·17	−1·93	48·24	0·20	4·352 994 3	22 542·10
				06·95			0·59		
13	Dreyer	84	03	50·44	+2·03	52·47	0·16	4·264 505 3	18 386·76
	Insane Asylum	49	47	08·94	+0·37	09·31	0·16	4·149 726 7	14 116·49
	Clarks Mound	46	08	58·34	+0·36	58·70	0·16	4·124 866 1	13 331·10
				57·72			0·48		
14	Kleinschmidt	49	29	59·38	−1·34	58·04	0·18	4·264 505 3	18 386·76
	Insane Asylum	101	44	32·32	−0·36	31·96	0·17	4·374 278 9	23 674·40
	Clarks Mound	28	45	27·99	+2·54	30·53	0·18	4·065 715 1	11 633·63
				59·69			0·53		
15	Kleinschmidt	71	57	57·90	−0·39	57·51	0·11	4·124 866 1	13 331·10
	Insane Asylum	51	57	23·38	−0·73	22·65	0·10	4·043 016 7	11 041·21
	Dreyer	56	04	42·32	−2·17	40·15	0·10	4·065 715 2	11 633·63
				03·60			0·31		
16	Kleinschmidt	22	27	58·52	+0·95	59·47	0·09	4·149 726 7	14 116·49
	Clarks Mound	17	23	30·35	−2·19	28·16	0·08	4·043 016 6	11 041·21
	Dreyer	140	08	32·76	−0·14	32·62	0·08	4·374 278 9	23 674·40
				01·63			0·25		

PROBABLE ERRORS.

Determination of the probable errors of the length of the sides common to the net and the adjacent chains of triangulation.

For the side Sugar Loaf Mound to Clarks Mound, as adjusted, we make use of the expression—

$$\frac{\text{Sugar Loaf Mound to Clarks Mound}}{\text{American Bottom Base}}=\frac{\sin(8-5)\sin(3-2)\sin(12-9)}{\sin(11-10)\sin(24-21)\sin(29-28)}$$

hence the function

$$F=\log\sin(8-5)+\log\sin(3-2)+\log\sin(12-9)-\log\sin(11-10)-\log\sin(24-21)-\log\sin(29-28)$$

Establishing and solving the transfer equations, we find the reciprocal of the weight $\frac{1}{p}=46{\cdot}04$, also the mean error m_F and the probable error r_F, both expressed in units of the sixth place of decimals in their logarithms, viz: $\pm 8{\cdot}25$ and $\pm 5{\cdot}56$,

respectively, hence log distance Sugar Loaf Mound to Clarks Mound 4·164 534 3 ± 5 6 and the distance 14 606·10 ± 0·19 metres. The probable error is about $\frac{1}{78\,000}$ part of the length. To this must be added the proportional error depending upon that of the base measure, or $\pm 0{\cdot}0206 \times \frac{14\ 606}{7\ 267} = \pm 0{\cdot}041$ metre; hence probable error in length of side Sugar Loaf Mound to Clarks Mound $\sqrt{(0{\cdot}19)^2 + (0{\cdot}041)^2} = \pm 0{\cdot}19$ metre.

For the side Clarks Mound to Dreyer we use the expression—

$$\frac{\text{Clarks Mound to Dreyer}}{\text{American Bottom Base}} = \frac{\sin(4-1)\sin(7-6)\sin(19-18)}{\sin(17-16)\sin(30-27)\sin(33-32)}$$

$$F = \log\sin(4-1) + \log\sin(7-6) + \log\sin(19-18) - \log\sin(17-16) - \log\sin(30-27) - \log\sin(33-32)$$

Establishing and solving the transfer equations, we get $\frac{1}{p} = 40{\cdot}94$, also $m_F = \pm 7{\cdot}78$ and $r_F = \pm 5{\cdot}25$, hence log distance Clarks Mound to Dreyer 4·149 726 7 ± 5 2 and distance 14 116·49 ± 0·17 metres. The probable error is about $\frac{1}{83\,000}$ part of the length. Adding to this the proportional error due to that of the base measure, or $0{\cdot}0206 \times \frac{14\ 116}{7\ 267} = \pm 0{\cdot}040$ metre, we have probable error of length of side Clarks Mound to Dreyer $\sqrt{(0{\cdot}17)^2 + (0{\cdot}040)^2} = \pm 0{\cdot}17$ metre.

For the side Minoma to Insane Asylum we use the expression—

$$\frac{\text{Minoma to Insane Asylum}}{\text{American Bottom Base}} = \frac{\sin(8-5)\sin(2-1)}{\sin(11-10)\sin(17-14)}$$

$$F = \log\sin(8-5) + \log\sin(2-1) - \log\sin(11-10) - \log\sin(17-14)$$

Establishing and solving the transfer equations, we find the reciprocal of the weight $\frac{1}{p} = 41{\cdot}48$, also the mean error $m_F = \pm 7{\cdot}83$ and probable error $r_F = \pm 5{\cdot}28$; hence log distance Minoma to Insane Asylum 4·025 166 1 ± 5 3 and distance 10 596·59 ± 0·13 metres. The probable error is about $\frac{1}{82\,000}$ part of the length. Adding to this the proportional error due to that of the base measure, or $0{\cdot}0206 \times \frac{10\ 597}{7\ 267} = \pm 0{\cdot}030$ metre, we have probable error of length Minoma to Insane Asylum $\sqrt{(0{\cdot}13)^2 + (0{\cdot}030)^2} = \pm 0{\cdot}13$ metre.

For the side Insane Asylum to Kleinschmidt we use the expression—

$$\frac{\text{Insane Asylum to Kleinschmidt}}{\text{American Bottom Base}} = \frac{\sin(4-1)\sin(7-6)\sin(27-26)}{\sin(17-16)\sin(30-27)\sin(35-34)}$$

$$F = \log\sin(4-1) + \log\sin(7-6) + \log\sin(27-26) - \log\sin(17-16) - \log\sin(30-27) - \log\sin(35-34)$$

Establishing and solving the transfer equations, we find the reciprocal of the weight $\frac{1}{p} = 47{\cdot}36$, also the mean error $m_F = \pm 8{\cdot}42$ and the probable error $r_F = \pm 5{\cdot}68$,

hence log distance Insane Asylum to Kleinschmidt $4.065\,715\,1 \pm 57$ and distance $11\,633.63 \pm .15$ metres. The probable error is about $\frac{1}{77\,000}$ part of the length. Adding to this the proportional error due to that of the base measure, or $0.0206 \times \frac{11\,634}{7\,267} = 0.033$ metre, we have probable error of length Insane Asylum to Kleinschmidt $\sqrt{(0.15)^2 + (0.033)^2} = \pm 0.15$ metre.

DESCRIPTION OF STATIONS FORMING THE AMERICAN BOTTOM BASE NET—ILLINOIS AND MISSOURI.

American Bottom Lower Base, St. Clair County, Illinois; established in 1872 by C. H. Boyd. This station is situated on the west slope of the Illinois bluffs on the east side of the American bottom, opposite St. Louis, Missouri, on land belonging to Mr. Francis Simoin. The geodetic point is on the west side of the road running north from the Belleville rock road along the foot of the bluffs through the small settlement of French Village. It is about 1 mile from the rock road and one-fourth mile from the village, 4 metres west of the fence at the side of the road, and about 193 metres north of Mr. Davenroi's house. The center is marked by a cross cut on a copper bolt set in the top of a limestone monument 12 by 14 by 40 inches, having the letters U.S.C.S. cut on the side facing the base, 1872 on one side and BASE on another. An earthenware pyramid is buried 4 feet below the surface of the ground, under the cross on the copper bolt. Two reference stones were set, one in prolongation of the base, distant 39.37 feet, and the other at right angles to the eastward, distant 63 feet from the center.

American Bottom Upper Base, Madison County, Illinois; established in 1872 by C. H. Boyd. This station is situated on the west slope of the Illinois bluffs on the east side of the American bottom, opposite St. Louis, Missouri, on land belonging to Mr. A. Sumner. The geodetic point is about one-fourth mile north of the road from East St. Louis to Collinsville and a short distance east of the road running north from the Collinsville road along the foot of the bluffs. The center is marked by a cross cut on a copper bolt set in the top of a limestone monument 12 by 14 by 40 inches, inscribed in a similar manner as the monument at Lower Base. An earthenware pyramid is buried 4 feet below the surface of the ground directly under the cross on the copper bolt. Two reference posts were set, one in prolongation of the base and one at right angles to the eastward, each 5 by 5 by 30 inches and distant 24 feet from the center.

Minoma, St. Louis County, Missouri; established in 1872 by C. H. Boyd. This station is on the cupola of the residence of Mr. Jefferson Clark, situated about one-half mile north of the Natural Bridge road and about 7 miles from St. Louis. The geodetic point is the center of the flagstaff on top of the cupola.

Insane Asylum, St. Louis County, Missouri; established in 1871 by R. E. Halter. This asylum, also known as the "County Lunatic Asylum," is situated on the "County farm forming part of a larger tract of land known as the "Gratiot League Square." It is about 5 miles southwesterly from the court-house at St. Louis and about 500 feet south of the Arsenal street road, at a point about one-half mile westerly from its intersection with the Kings Highway. The geodetic point is the finial of the cupola of the building. Eccentric points were occupied on the main floor of the cupola.

Sugar Loaf Mound, Madison County, Illinois; established in 1871 by R. E. Halter. This station is situated near the middle of the north line of the northeast quarter of section

20, township 3 north, range 8 west, about 3 miles northwest of Collinsville on the Vandalia Railroad. It is on a very prominent mound on the edge of the bluffs, with a steep slope in all directions falling off about 50 feet to the level ground to the eastward and 150 to 200 feet to the westward down to the American bottom. A small private graveyard is just south of the mound. The geodetic point is a little to the north of the center of the mound and is marked with the usual earthenware pyramid, the apex being 3·1 feet below the surface of the ground. The surface mark is a white marble post, 6 by 6 inches square and 2 feet and 6 inches long, projecting about 1 inch above the ground, having cross lines cut on the top with the letters U.S.C.& G.S. cut in the four squares.

Clarks Mound, St. Clair County, Illinois; established in 1871 by R. E. Halter. This station is situated near the middle of the south line of the northwest quarter of section 35, township 2 north, range 9 west, directly on the bluffs overlooking the American bottom, about three-fourths mile south of French Village and about 7½ miles northwest of Belleville. The mound is quite prominent, the property, in 1880, of Mr. William Clark, of St. Louis. The underground mark is the center of the bottom of a soda-water bottle buried, bottom up, 2 feet and 7 inches below the surface of the ground. The surface mark is (in 1880) a white marble post 6 inches square, 2 feet 6 inches long, projecting about 2 inches above the ground, the top cut and inscribed like the one at Sugar Loaf Mound. Two white marble posts, 4 inches square, 2 feet 6 inches long, with diagonal lines cut on the top, an arrowhead at the end of one of the lines pointing to the station, were set as reference marks; one in prolongation of the line to the Blind Asylum, St. Louis, and the other in prolongation of the line to Sugar Loaf Mound, each 50 feet distant. Additional reference marks are nails in the centers of triangles cut on 3 trees, as follows:

A hickory 64·3 feet distant, bearing north 41° 30′ east; a white oak 39·3 feet distant, bearing south 57° 30′ east, and a hickory 92·2 feet distant, bearing south 51° 30′ east—bearings magnetic.

Dreyer, St. Clair County, Illinois; established in 1871 by R. E. Halter. This station is situated in the southern part of section 27, township 1 north, range 10 west, on the bluffs, about 6 miles northwest of Centerville, about 1½ miles nearly south of Falling Springs, and nearly east of where the Carondelet rock road, which crosses the bottom, strikes the bluffs. It is on land belonging to Friedrich Dreyer, about 370 metres west by north from his house and about 17 metres north of the road leading to the bluffs. The apex of an earthenware pyramid, 3 feet below the surface, marks the geodetic point. The surface mark is a spike in the center of a cedar stub, 4 by 4 by 30 inches, projecting about 3 inches above the ground. A white marble post, 6 by 6 by 29 inches, with cross lines cut on top and the letters U.S.C.& G.S. cut in the four squares, was set south of the station in the fence line north of the road, a trifle below the surface, distant 64·43 feet from the geodetic point and 1 210 feet from the northwest corner of Dreyer's corn house. Two other marble posts, 4 by 4 by 30 inches, with diagonal lines (arrowhead at end of one line pointing to the station) were set in the fence line, projecting about 2 inches above the surface, as reference marks—one west and one east of the larger post, the west one distant 107·95 feet and the east one 76·55 from the geodetic point. The following angles were measured at the center: East stone, 0°·00′; south stone, 45°·09′; west stone, 90°·18′.

Kleinschmidt, St. Louis County, Missouri; established in 1871 by R. E. Halter. This station is situated in township 44 north, range 6 east of the fifth principal meridian, on an eminence known as Terrills Hill in the southwest part of the commons of Carondelet, south of the River des Peres, on lot belonging to Henry Kleinschmidt, at northeast corner of intersection of Lemay Ferry and Sappington Barracks roads. The apex of an earthenware pyramid, set 2 feet and 4 inches below the surface of the ground, marks the geodetic point. The surface mark is a tenpenny nail in the center of a white pine stub 4 inches square. Two cedar stubs were set, 41 feet apart, within 1 foot of the fence on the north side of the Sappington Barracks road, as reference marks—one due south of the geodetic point, 41 feet 4 inches distant, and 132 feet distant from the east corner of the lot, the other 37 feet 7 inches distant from the geodetic point and 225½ feet from the west corner of the lot. Distance from geodetic point to southeast corner of rock foundation of Kleinschmidt's house is 149 feet, and to northeast corner of rock foundation of Bauer's house, south of Sappington Barracks road, 165 feet and 3 inches. The angle at the station between the house corners is 75° 18′.

(*c*) *Olney Base Line, Illinois, 1879.*

LOCATION, MEASUREMENT, AND LENGTH.

This base line is due to the labors of the United States Lake Survey, and, on account of its position with reference to the transcontinental triangulation and its high accuracy, has been incorporated into the scheme of triangulation passing over this region between the American Bottom Base, Illinois, and the Holton Base, Indiana. A full account of the measure of this base is given in "Report* upon the Primary Triangulation of the United States Lake Survey by Lieut. Col. C. B. Comstock, Corps of Engineers, brevet brigadier-general, United States Army, aided by the assistants of the Survey," to which the reader is referred who may desire more information than what is given here, viz, a brief abstract of a chapter (XII) in that publication.

The Olney Base is situated on a prairie in the southern part of Jasper County, Illinois, about 13 kilometres (say 8 statute miles) from Olney, about one-half the length of the line being on cultivated ground and the other on unbroken prairie sod. The line is a straight one, and the greatest difference of elevation of its points is but 7 meters (23 feet); its length is approximately 6·59 kilometres (4·09 statute miles); its middle point is in latitude 38° 51′·8 and in longitude 88° 03′·9 west, nearly. The azimuth of the line at the west end is 268° 30′ west of south, about. The ends of the base were marked by granite posts set in brickwork, and the terminals are agate hemispheres set in brass cylinders leaded into granite posts, and are 3 feet below the surface of the ground. The base was divided into 6 nearly equal sections by marks on stones, the mark being a drill hole in the top of a copper bolt leaded into the stone. Each of these sections was measured in duplicate in opposite directions.

The measurement was made with the Repsold apparatus by a party under the charge of Assistant Engineer E. S. Wheeler, between July 9 and September 15, 1879. This apparatus arrived at the Survey office, Detroit, in November, 1876. With it the measurement is made with one tube, which is 4 meters long, and is a metallic thermometer consisting of a bar of zinc and a bar of steel joined at their middle points; the tube

* Professional Papers of the Corps of Engineers, United States Army, No. 24, Washington, 1882, pp. 300–305.

lengths are defined between microscopes provided with reading micrometers for measuring intervals between successive tube ends and mounted on stable iron stands, so constructed as to admit of all needed adjustments of the microscopes over the ends of the tube. A full description, with plates, of the apparatus and of the manner of using it will be found in Chapter VIII of the "Professional Papers, Corps of Engineers, United States Army, No. 24."

When used in the field, the tube and microscopes are protected from heat radiation by awnings. The apparatus was accompanied by a steel meter designated "R. 1876." A line of levels was run along the base line and checked by the observed inclinations of the tubes. The average height of these tubes above the mean tidal level of the ocean, as found by combinations of various levels, is given for the western part of the Olney base 489·7 ± 5·0 feet (149·25 metres ± 1·52) and for the eastern part 480·5 ± 5·0 feet (146·45 metres ± 1·52). The resulting length and its probable error are given on pages 303–304 in terms of the Repsold Metre.

$$\text{Olney Base at sea level} = 6\,589{\cdot}2 \left(R\ 1876 \text{ at} \begin{cases} 60^\circ{\cdot}29\ \text{F.} \\ 15^\circ{\cdot}717\text{C.} \end{cases}\right) - 165{\cdot}04\,mm \pm 3{\cdot}48\,mm.$$

In order to obtain a reliable value for the length of this metre, it was sent to the International Bureau of Weights and Measures at Sevres, France, in April, 1882, for comparison with the standards of that Bureau. The results are given in Tome III, Travaux et Mémoires du Bureau International des Poids et Mesures. Paris, 1884. The expansion of R 1876 for $1^\circ C.$ was $\underset{\pm\ {\cdot}011}{10{\cdot}563\mu}$; at that time, however, the length of the Prototype Metre had not been finally adopted, though the uncertainty was supposed not to exceed a few tenths of a micron. The value given is $R\ 1876 = 1m + 97{\cdot}81\mu$ at $0^\circ C.$

We have next the result from direct comparisons of the Committee and the Repsold metres made by Assistant O. H. Tittmann at Washington, District of Columbia, between August, 1888, and March, 1889, for which result see "The relation between the metric standards of length of the United States Coast and Geodetic Survey and the United States Lake Survey." A report by C. A. Schott and O. H. Tittmann, Assistants.* From these elaborate observations we have the result (p. 185):

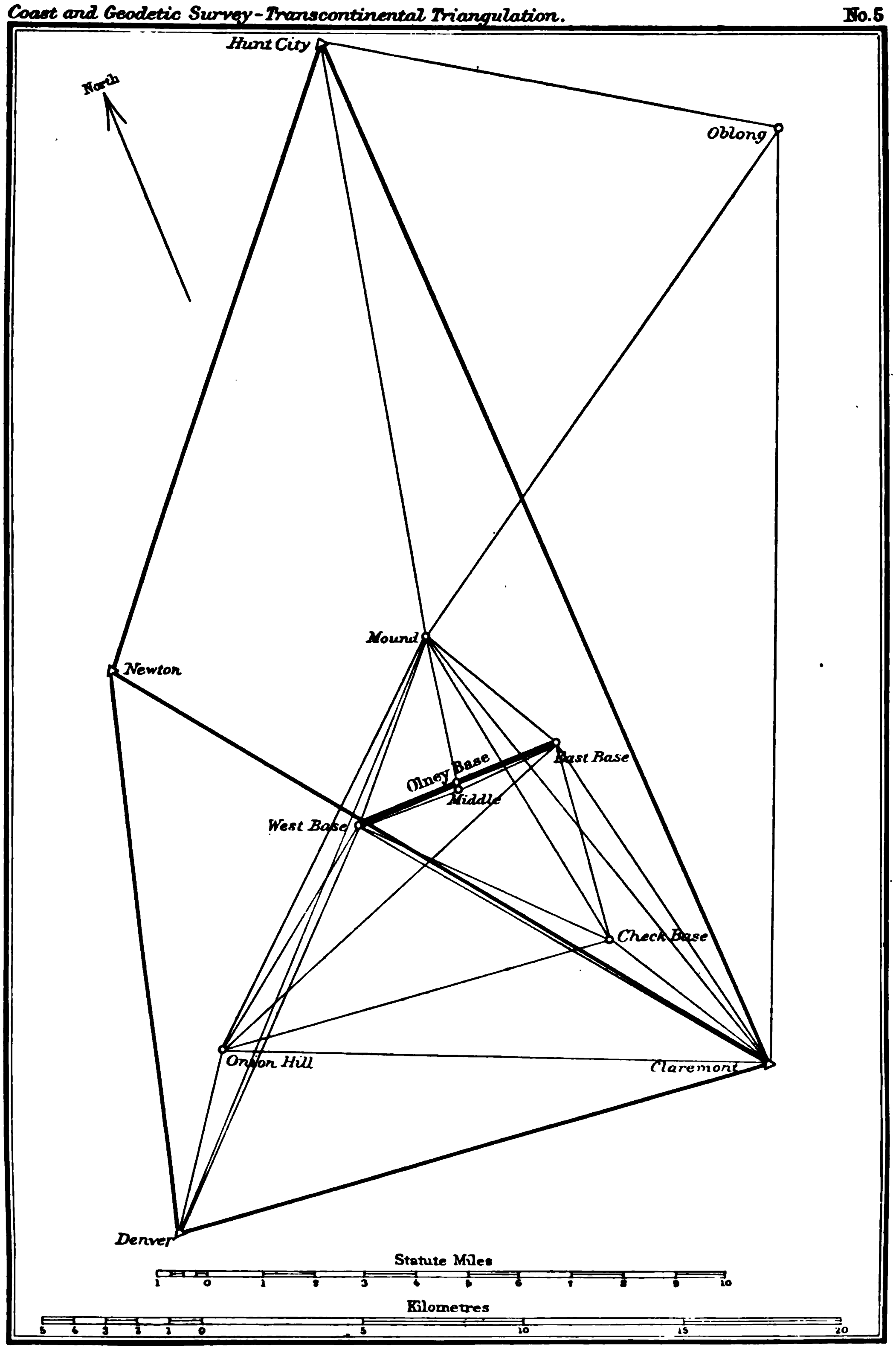
$$R\ 1876 = \text{Committee Metre} + 98{\cdot}19\mu \pm 0{\cdot}70\mu \text{ at } 0^\circ C.,$$

a result almost identical with that obtained at Paris. In the same report we find a comparison of the several independently determined values for the expansion of R 1876, all in excellent agreement, and we therefore adopt the values $\alpha_{R\,1876} = 10{\cdot}606\mu$ and $\alpha_{C.M.} = 11{\cdot}795\mu$ (p. 186); further we take the Committee Metre to represent in length the International or Prototype Metre. In this connection see the discussion relating to the standard of length of the transcontinental triangulation, in fact relating to all distances determined by the Survey.

Substituting the value of $R_{1876} = 1m + 98{\cdot}2\mu \pm 0{\cdot}7\mu$ at $0^\circ C.$ into the equation given above for length of base, we find it to be 6 590·780 4 metres, and if we take $\pm 1\mu$ for the probable error of the length of the Repsold bar,† that of the base becomes $\sqrt{(6{\cdot}6)^2 + (3{\cdot}5)^2}\,mm.$ or $\pm 7{\cdot}5\,mm.$ which is about $\frac{1}{878\,800}$ part of the length of the base.

* Appendix No. 6, Coast and Geodetic Survey Report for 1889.

† This can not be considered too large if we remember that the direct comparison of line and end measures offers special difficulty, particularly when the *reflex* method is applied to the end surface.



OLNEY BASE NET, ILL. 1879 TO 1884.

This may be taken to represent the measuring error, combining it with the probable error due to our practical unit of length, the Committee Metre, taken as $\pm \frac{3}{4}\mu$ we get $\sqrt{(7{\cdot}5)^2+(4{\cdot}9)^2} = \pm 8{\cdot}9mm.$, or about $\frac{1}{740000}$ part of the length. We therefore have the final value for length of base 6 590·780 4$m.$ $\pm$ 8 9, and its logarithm 3·818 936 84 $\pm$ 59

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE OLNEY BASE NET 1879, 1883–84.

Olney East Base, Jasper County, Illinois. November, 1879. 35-centimetre theodolite, T. & S., No. 4. Telescope above ground 11·43 metres. J. H. Darling, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″
39	Claremont	0	00	00·00	−0·43	59·57
40	Check Base	18	20	42·11	+0·35	42·46
41	Onion Hill	81	38	03·54	+0·35	03·89
42	Olney Middle Base	101	56	20·04	−0·10	19·94
43	Olney West Base	101	56	23·00	−0·06	22·94
44	Buffalo Mound	162	57	14·89	−0·12	14·77

Olney West Base, Jasper County, Illinois. October and November, 1879. 35-centimetre theodolites, T. & S., Nos. 3 and 4. Telescope above ground 15·70 metres. R. S. Woodward and J. H. Darling, observers.

		°	′	″	″	″
45	Buffalo Mound	0	00	00·00	−0·30	59·70
46	Olney East Base	47	46	00·53	+0·04	00·57
47	Olney Middle Base	47	46	03·17	+0·40	03·57
48	Check Base	94	31	34·71	+0·29	35·00
49	Claremont	99	54	21·74	+0·03	21·77
50	Denver	183	16	48·00	+0·15	48·15
51	Onion Hill	190	48	14·04	−0·61	13·43

Olney Middle Base, Jasper County, Illinois. October, 1879. 25-centimetre theodolite, R., No. 1. Telescope above ground 1·98 metres. E. S. Wheeler, observer.

		°	′	″	″	″
58	Olney West Base	0	00	00·00	−0·43	59·57
59	Buffalo Mound	100	04	09·23	+0·38	09·61
60	Olney East Base	179	59	53·52	+0·05	53·57

Check Base, Richland County, Illinois. November and December, 1879. 35-centimetre theodolite, T. and S., No. 4. Telescope above ground 12·95 metres. J. H. Darling, observer.

		°	′	″	″	″
34	Claremont	0	00	00·00	+0·60	00·60
35	Onion Hill	127	15	17·17	−0·17	17·00
36	Olney West Base	167	12	31·73	−0·07	31·66
37	Buffalo Mound	200	59	15·44	−0·39	15·05
38	Olney East Base	216	51	16·82	+0·03	16·85

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE OLNEY BASE NET 1879, 1883-84—continued.

Onion Hill, Richland County, Illinois. November, 1879. 35-centimetre theodolite, T. and S., No. 3. Telescope above ground 1·83 metres. R. S. Woodward, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″
52	Buffalo Mound	0	00	00·00	+0·21	00·21
53	Olney West Base	4	40	27·96	−0·08	27·88
54	Olney East Base	21	19	56·39	−0·34	56·05
55	Check Base	48	26	34·48	+0·49	34·97
56	Claremont	65	34	23·07	+0·07	23·14
57	Denver	166	59	12·21	−0·35	11·86

Oblong, Crawford County, Illinois. October and November, 1879. 35-centimetre theodolite, P. and M., No. 2. Telescope above ground 30·94 metres. G. Y. Wisner, observer.

		°	′	″	″	″
22	Claremont	0	00	00·00	+0·37	00·37
23	Buffalo Mound	34	36	31·20	−0·38	30·82
24	Hunt City	100	27	20·78	+0·02	20·80
	Casey	132	34	08·03		
	Belle Air	160	10	26·65		

Buffalo Mound, Jasper County, Illinois. October and November, 1879. 35-centimetre theodolite, T. and S., No. 1. Telescope above ground 31·24 metres. A. R. Flint, observer.

		°	′	″	″	″
25	Olney East Base	0	00	00·00	+0·08	00·08
26	Claremont	11	54	58·16	+0·36	58·52
27	Check Base	19	31	25·93	+0·09	26·02
28	Olney Middle Base	39	03	21·61	−0·27	21·34
29	Olney West Base	71	13	07·72	−0·26	07·46
30	Denver	73	29	29·29	+0·38	29·67
31	Onion Hill	77	20	53·39	+0·17	53·56
32	Hunt City	221	26	33·58	−0·62	32·96
33	Oblong	266	15	21·90	+0·07	21·97

Newton, Jasper County, Illinois. October 3 to October 16, 1883. 30-centimetre theodolite, No. 135. Telescope above ground 12·65 metres. G. A. Fairfield, observer.

		°	′	″	″	″
3	Denver	0	00	00·00	−0·13	$\overline{59}$·87
	Lucas	79	44	13·01		
	Island Creek	129	23	45·69		
1	Hunt City	205	20	35·47	+0·46	35·93
2	Claremont	307	38	00·83	−0·32	00·51

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·00.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE OLNEY BASE NET 1879, 1883–84—continued.

Denver, Richland County, Illinois. November, 1879. 35-centimetre theodolite, T. & S., No. 3. Telescope above ground 23·16 metres. R. S. Woodward, observer.—November 12 to December 2, 1883. 30-centimetre theodolite, No. 135. Telescope above ground 23·16 metres. G. A. Fairfield observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″
4	Newton	0	00	00·00	+0·70	00·70
5	Onion Hill	19	57	16·27	+0·09	16·36
6	Buffalo Mound	29	06	41·03	−0·16	40·87
7	Olney West Base	30	07	07·33	−0·19	07·14
8	Claremont	80	43	13·71	−0·44	13·27
	Parkersburg	129	20	12·16		
	Holtzhausen	260	42	27·11		
	Lucas	300	13	46·61		
	Island Creek	330	03	35·36		

Probable error of a single observation of a direction ($D.$ and $R.$) $= \pm 1''{\cdot}01$ in 1883.

Hunt City, Jasper County, Illinois. October, 1879. 35-centimetre theodolite, T. & S., No. 3. Telescope above ground 23·32 metres. R. S. Woodward, observer.—September 5 to September 17, 1884. 30-centimetre theodolite, No. 107. Telescope above ground 23·32 metres. G. A. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″
	Belle Air	0	00	00·00		
	Honey Creek	74	41	37·75		
18	Oblong	75	44	47·03	+0·12	47·15
19	Claremont	131	01	27·19	−0·07	27·12
20	Buffalo Mound	145	05	08·91	−0·12	08·79
21	Newton	173	22	02·19	+0·07	02·26
	Island Creek	232	34	09·67		
	Casey	313	18	25·33		

Probable error of a single observation of a direction ($D.$ and $R.$) $= \pm 1''{\cdot}25$ in 1884.

Claremont, Richland County, Illinois. November, 1879. 35-centimetre theodolite, P. & M., No. 2. Telescope above ground 24·84 metres. G. Y. Wisner, observer.—July 26 to August 22, 1884. 30-centimetre theodolite, No. 107. Telescope above ground 24·84 metres. G. A. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″
9	Denver	0	00	00·00	+0·65	00·65
10	Onion Hill	17	49	15·39	−0·12	15·27
11	Olney West Base	46	01	29·05	−0·41	28·64
12	Newton	46	54	49·55	−0·01	49·54
13	Check Base	53	26	11·07	−0·21	10·86
14	Buffalo Mound	66	48	58·15	−0·30	57·85
15	Olney East Base	71	56	44·50	−0·23	44·27
16	Hunt City	82	16	50·46	+0·56	51·02
17	Oblong	106	32	51·56	+0·07	51·63
	Honey Creek	138	23	11·73		
	Summit	174	40	19·45		
	Parkersburg	274	17	40·86		

Probable error of a single observation of a direction ($D.$ and $R.$) $= \pm 1''{\cdot}03$ in 1884.

FIGURE ADJUSTMENT.

*Observation equations.**

No.	
1	$0 = +1.60 + (12) - (9) + (8) - (4) + (3) - (2)$
2	$0 = +0.08 + (21) - (19) + (16) - (12) + (2) - (1)$
3	$0 = +1.21 - (30) - (26) + (14) - (9) + (8) - (6)$
4	$0 = +1.02 + (24) - (22) + (17) - (16) + (19) - (18)$
5	$0 = -0.85 + (24) - (23) + (33) - (32) + (20) - (18)$
6	$0 = +0.09 + (26) - (33) + (23) - (22) + (17) - (14)$
7	$0 = +1.72 + (57) - (56) + (10) - (9) + (8) - (5)$
8	$0 = +0.51 + (56) - (52) + (31) - (26) + (14) - (10)$
9	$0 = +1.18 + (50) - (49) + (11) - (9) + (8) - (7)$
10	$0 = +0.18 + (49) - (45) + (29) - (26) + (14) - (11)$
11	$0 = +0.77 + (51) - (49) + (11) - (10) + (56) - (53)$
12	$0 = -1.08 + (41) - (39) + (15) - (10) + (56) - (54)$
13	$0 = -0.53 + (43) - (39) + (15) - (11) + (49) - (46)$
14	$0 = -1.03 + (38) - (35) + (55) - (54) + (41) - (40)$
15	$0 = +1.28 + (35) - (34) + (13) - (10) + (56) - (55)$
16	$0 = +0.06 + (43) - (40) + (38) - (36) + (48) - (46)$
17	$0 = +0.04 + (44) - (40) + (38) - (37) + (27) - (25)$
18	$0 = -1.53 + (59) - (58) + (47) - (45) + (29) - (28)$
19	$0 = +0.71 + (60) - (59) + (28) - (25) + (44) - (42)$
20	$0 = -0.88 + (60) - (58) + (47) - (46) + (43) - (42)$
21	$0 = +0.32 + (43) - (42) - (47) + (46)$
22	$0 = -3.0 + .46(1) + 1.16(2) - 1.62(3) - .34(4) + 1.67(6) - 1.33(8) - 6.10(19) + 8.41(20)$ $- 2.31(21) + 2.58(26) + 1.14(30) - 3.72(32)$
23	$0 = +3.2 + 5.07(14) - 7.61(16) + 2.54(17) + .79(18) - 8.41(19 + 7.62(20) + 3.05(22) - 3.99(23)$ $+ .94(24)$
24	$0 = -0.4 - 2.60(25) + 5.95(28) - 3.35(29) + 1.17(42) - 1.17(44) - 1.91(45) + 1.91(47)$
25	$0 = -1.666 - 1.1744(5) + 11.975(6) - 10.8006(7) - 3.3447(29) + 5.3054(30) - 1.9607(31)$ $- 2.5751(52) + 1.9149(53) + .6602(57)$
26	$0 = +5.45 - 11.744(5) + 13.473(7) - 1.729(8) - 2.032(9) + 3.926(10) - 1.894(11) - 7.774(53)$ $+ 1.172(56) + 6.602(57)$
27	$0 = +18.65 - 3.926(10) + 9.471(11) - 5.545(14) - 1.250(26) + 20.857(29) - 19.607(31)$ $- 25.751(52) + 26.923(53) - 1.172(56)$
28	$0 = +1.71 - 3.926(10) + 8.258(11) - 4.332(15) + .445(39) + 5.69(41) - 6.135(43) - 5.865(53)$ $+ 7.037(54) - 1.172(56)$
29	$0 = +3.76 - 11.854(11) + 16.186(13) - 4.332(15) - 9.273(34) + 7.484(36) + 1.789(38) + .445(39)$ $+ .236(40) - .681(43)$
30	$0 = +0.77 - 2.513(35) + 4.302(36) - 1.789(38) - .236(40) + 5.69(41) - 5.454(43) - 4.839(53)$ $+ 7.037(54) - 2.198(55)$
31	$0 = -0.26 - 1.213(11) + 5.545(14) - 4.332(15) - .716(25) + 1.25(26) - .534(29) + .445(39)$ $+ .721(43) - 1.166(44)$
32	$0 = +0.88 - .716(25) + 1.663(27) - .947(29) - 1.359(36) + 3.148(37) - 1.789(38) - .236(40)$ $+ 1.402(43) - 1.166(44)$

* Number of angle equations 21 and of side equations 11; in establishing the latter either 7 or 8 places in the logarithms are used and the logarithmic differences for 1″ are given in units of the sixth place, with one exception.

Correlate equations.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
(1)		−1													
(2)	−1	+1													
(3)	+1														
(4)	−1														
(5)	...	...	...	...	...	...	−1	...	...	...	...	...	...	...	...
(6)			−1												
(7)									−1						
(8)	+1		+1				+1		+1						
(9)	−1		−1				−1		−1						
(10)	...	...	...	...	...	...	+1	−1	...	...	−1	−1	...	...	−1
(11)									+1	−1	+1		−1		
(12)	+1	−1													
(13)															+1
(14)			+1			−1		+1		+1					
(15)	...	...	...	...	...	...	...	...	...	...	...	+1	+1	...	...
(16)		+1		−1											
(17)				+1		+1									
(18)				−1	−1										
(19)		−1		+1											
(20)	...	...	...	...	+1	...	...	...	...	...	...	...	...	...	...
(21)		+1													
(22)				−1		−1									
(23)					−1	+1									
(24)				+1	+1										
(25)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
(26)			−1			+1		−1		−1					
(27)															
(28)															
(29)										+1					
(30)	...	..	+1	...	...	...	...	...	...	...	...	...	...	...	...
(31)								+1							
(32)					−1										
(33)					+1	−1									
(34)															−1
(35)	...	...	...	..	...	...	...	...	...	...	...	...	...	−1	+1
(36)															
(37)															
(38)														+1	
(39)												−1	−1		
(40)	...	...	...	...	...	...	...	...	...	...	...	...	...	−1	...
(41)												+1		+1	
(42)															

Correlate equations—Continued.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
(43)													+1		
(44)															
(45)	...	...	...	...	...	...	...	...	...	−1	...	...	...	...	...
(46)													−1		
(47)															
(48)															
(49)									−1	+1	−1		+1		
(50)	...	...	...	...	...	...	...	...	+1	...	...	...	...	...	...
(51)											+1				
(52)								−1							
(53)											−1				
(54)												−1		−1	
(55)	...	...	...	...	...	...	...	...	...	...	...	...	...	+1	−1
(56)							−1	+1			+1	+1			+1
(57)							+1								

Correlate equations—Continued.

Corrections.	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}
(1)							+0·46			
(2)							+1·16			
(3)							−1·62			
(4)							−0·34			
(5)	...	...	...	...	...	...	......	......	......	− 1·174 4
(6)							+1·67			+11·975
(7)										−10·800 6
(8)							−1·33			
(9)										
(10)	...	...	...	...	...	...	......	......	......	....
(11)										
(12)										
(13)										
(14)								+5·07		
(15)	...	...	...	...	...	...	......	......	......	....
(16)								−7·61		
(17)								+2·54		
(18)								+0·79		
(19)							−6·10	−8·41		
(20)	...	...	...	...	...	...	+8·41	+7·62	......	....
(21)							−2·31			
(22)								+3·05		
(23)								−3·99		

Correlate equations—Continued.

Corrections.	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}
(24)								+0·94		
(25)	...	−1	...	−1	...	...	......	......	−2·60	....
(26)							+2·58			
(27)		+1								
(28)			−1	+1					+5·95	
(29)			+1						−3·35	− 3·344 7
(30)	...	...	...	...	...	...	+1·14	......	......	+ 5·305 4
(31)										− 1·960 7
(32)							−3·72			
(33)										
(34)										
(35)	...	...	...	...	...	...	......	.....	......	....
(36)	−1									
(37)		−1								
(38)	+1	+1								
(39)										
(40)	−1	−1	...	...	...	...	......	......	......	....
(41)										
(42)				−1	−1	−1			+1·17	
(43)	+1				+1	+1				
(44)		+1		+1					−1·17	
(45)	...	...	−1	...	...	...	......	......	−1·91	....
(46)	−1				−1	+1				
(47)			+1		+1	−1			+1·91	
(48)	+1									
(49)										
(50)	...	...	...	...	...	...	......	......	......	....
(51)										
(52)										− 2·575 1
(53)										+ 1·914 5
(54)										
(55)	...	...	...	...	...	...	......	......	......	....
(56)										
(57)										+ 0·660 2
(58)			−1		−1					
(59)			+1	−1						
(60)	...	...	...	+1	+1	...	......	......	......	....

Correlate equations—Continued.

Corrections.	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}
(1)							
(2)							
(3)							
(4)							
(5)	−11·744	....	....	....	....	....	....
(6)							
(7)	+13·473						
(8)	− 1·729						
(9)	− 2·032						
(10)	+ 3·926	− 3·926	−3·926	....	....	....	....
(11)	− 1·894	+ 9·471	+8·.58	−11·854		−1·213	
(12)							
(13)				+16·186			
(14)		− 5·545				+5·545	
(15)	....	....	−4·332	− 4·332	....	−4·332	....
(16)							
(17)							
(18)							
(19)							
(20)	....	....	....	....	....	....	....
(21)							
(22)							
(23)							
(24)							
(25)	....	....	....	....	....	−0·716	−0·716
(26)		− 1·250				+1·25	
(27)							+1·663
(28)							
(29)		+20·857				−0·534	−0·947
(30)	....	....	....	....	....	....	....
(31)		−19·607					
(32)							
(33)							
(34)				− 9·273			
(35)	....	....	....	....	−2·513	....	....
(36)				+ 7·484	+4·302		−1·359
(37)							+3·148
(38)				+ 1·789	−1·789		−1·789
(39)			+0·445	+ 0·445		+0·445	
(40)	....	....	....	+ 0·236	−0·236	....	−0·236
(41)			+5·69		+5·69		
(42)							

Correlate equations—Completed.

Corrections.	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{71}	C_{31}
(43)			−6·135	− 0·681	−5·454	+0·721	+1·402
(44)						−1·166	−1·166
(45)	....	....	....	....	....	....	....
(46)							
(47)							
(48)							
(49)							
(50)	....	....	....	....	....	....	....
(51)							
(52)		−25·751					
(53)	− 7·774	+26·923	−5·865		−4·839		
(54)			+7·037		+7·037		
(55)	....	....	....	....	−2·198	....	....
(56)	+ 1·172	− 1·172	−1·172				
(57)	+ 6·602						

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
0 = + 1·60	+6	−2	+2				+2		+2						
+ 0·08		+6		−2											
+ 1·21			+6			−2	+2	+2	+2	+2					
+ 1·02				+6	+2	+2									
− 0·85					+6	−2									
+ 0·09						+6		−2		−2					
+ 1·72							+6	−2	+2		−2	−2			−2
+ 0·51								+6		+2	+2	+2			+2
+ 1·18									+6	−2	+2		−2		
+ 0·18										+6	−2		+2		
+ 0·77											+6	+2	−2		+2
− 1·08												+6	+2	+2	+2
− 0·53													+6		
− 1·03														+6	−2
+ 1·28															+6

Normal equations—Continued.

	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}
+ 1·60							− 3·77			
+ 0·08							+ 4·49	+ 0·80		
+ 1·21							− 4·44	+ 5·07		− 6·6696
+ 1·02							− 6·10	− 1·16		
− 0·85							+ 12·13	+ 11·76		
+ 0·09							+ 2·58	− 9·57		
+ 1·72							− 1·33			+ 1·8346
+ 0·51							− 2·58	+ 5·07		+ 0·6144
+ 1·18							− 1·33			+ 10·8006
+ 0·18			+2				− 2·58	+ 5·07	− 1·44	− 3·3447
+ 0·77										− 1·9149
− 1·08										
− 0·53	+2				+2					
− 1·03	+2	+2								
+ 1·28										
0 = + 0·06	+6	+2			+2					
+ 0·04		+6		+2					+ 1·43	
− 1·53			+6	−2	+2	−1			− 5·48	− 3·3447
+ 0·71				+6	+2	+1			+ 6·21	
− 0·88					+6				+ 0·74	
+ 0·32						+4			− 3·08	
− 3·0							+143·924	+115·385		+ 26·046
+ 3·2								+245·59		
− 0·4									+63·42	+ 11·205
− 1·666										+315·345

Normal equations—Completed.

	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}
+ 1·60	+ 0·303						
+ 0·08							
+ 1·21	+ 0·303	− 4·295				+ 4·295	
+ 1·02							
− 0·85							
+ 0·09		+ 4·295				+ 4·295	
+ 1·72	+ 21·403	− 2·754	− 2·754				
− 0·51	− 2·754	+ 4·603	+ 2·754			+ 4·295	
+ 1·18	− 15·064	+ 9·471	+ 8·258	− 11·854		− 1·213	
+ 0·18	+ 1·894	+ 7·091	− 8.258	+ 11·854		+ 4·974	− 0·947
+ 0·77	+ 3·126	− 14·698	+ 16·877	− 11·854	+ 4·839	− 1·213	
− 1·08	− 2·754	+ 2·754	− 3·370	− 4·777	− 1·347	− 4·777	
− 0·53	+ 1·894	− 9·471	− 19·170	+ 6·396	− 5·454	− 2·843	+ 1·402
− 1·03			− 1·347	+ 1·553	− 2·585		− 1·553
+ 1·28	− 2·754	+ 2·754	+ 2·754	+ 25·459	− 0·315		
+ 0·06			− 6·135	− 6·612	− 11·309	+ 0·721	+ 1·208
+ 0·04				+ 1·553	− 1·553	− 0.450	− 3·488
− 1·53		+ 20·857				− 0·534	− 0·947
+ 0·71						− 0·450	− 0·450
− 0·88			− 6·135	− 0·681	− 5·454	+ 0·721	+ 1·402
+ 0·32			− 6·135	− 0·681	− 5·454	+ 0·721	+ 1·402
− 3·0	+ 2·299	− 3·225				+ 3·225	
+ 3·2		− 28·113				+28·113	
− 0·4		− 69·874				+ 5·015	+ 6·398
− 1·666	−142·251	+ 86·549	− 11·231		− 9·267	+ 1·786	+ 3·168
o=+ 5·45	+450·95	−244·025	+ 13·167	+ 22·451	+ 37·618	+ 2·298	
+18·65		+2346·21	− 62·905	−112·269	−130·280	−54·935	−19·752
+ 1·71			+257·877	− 74·748	+143·736	+ 4·524	− 8·601
+ 3·76				+567·19	+ 32·658	+32·851	−14·383
+ 0·77					+167·967	− 3·932	−10·237
− 0·26						+55·422	+ 3·389
+ 0·88							+22·513

Resulting values of correlates and of corrections to angular directions.

$C1=-0.598\ 2$	$C\ 9=+0.152\ 4$	$C17=+0.195\ 0$	$C25=+0.059\ 44$
2 $-0.590\ 4$	10 $+0.199\ 9$	18 $+0.066\ 6$	26 $+0.044\ 86$
3 $+0.390\ 3$	11 $-0.612\ 1$	19 $-0.314\ 5$	27 $-0.014\ 35$
4 $-1.745\ 2$	12 $+1.133\ 6$	20 $+0.365\ 7$	28 $+0.068\ 60$
5 $+1.688\ 3$	13 $-0.631\ 1$	21 $+0.065\ 9$	29 $+0.056\ 51$
6 $+1.618\ 0$	14 $-0.787\ 5$	22 $-0.286\ 7$	30 $-0.067\ 75$
7 $-0.685\ 7$	15 $-1.127\ 1$	23 $+0.078\ 6$	31 $+0.044\ 29$
8 $+0.003\ 5$	16 $+0.288\ 0$	24 $+0.018\ 44$	32 $-0.062\ 67$

Corrections:

(1) $=+0.458\ 5$	(16) $=+0.556\ 7$	(31) $=+0.168\ 4$	(46) $=+0.043\ 3$
(2) $-\ .324\ 8$	(17) $+\ .072\ 4$	(32) $-\ .621\ 8$	(47) $+\ .401\ 8$
(3) $-\ .133\ 7$	(18) $+\ .119\ 0$	(33) $+\ .070\ 3$	(48) $+\ .288\ 0$
(4) $+\ .695\ 7$	(19) $-\ .066\ 9$	(34) $+\ .603\ 1$	(49) $+\ .028\ 5$
(5) $+\ .089\ 1$	(20) $-\ .123\ 9$	(35) $-\ .169\ 3$	(50) $+\ .152\ 4$
(6) $-\ .157\ 3$	(21) $+\ .071\ 9$	(36) $-\ .071\ 5$	(51) $-\ .612\ 1$
(7) $-\ .190\ 0$	(22) $+\ .366\ 9$	(37) $-\ .392\ 3$	(52) $+\ .212\ 9$
(8) $-\ .437\ 5$	(23) $-\ .383\ 9$	(38) $+\ .029\ 9$	(53) $-\ .083\ 6$
(9) $+\ .650\ 0$	(24) $+\ .017\ 0$	(39) $-\ .427\ 2$	(54) $-\ .340\ 2$
(10) $-\ .120\ 5$	(25) $+\ .084\ 8$	(40) $+\ .348\ 6$	(55) $+\ .488\ 5$
(11) $-\ .406\ 5$	(26) $+\ .357\ 9$	(41) $+\ .350\ 9$	(56) $+\ .072\ 6$
(12) $-\ .007\ 8$	(27) $+\ .090\ 8$	(42) $-\ .095\ 5$	(57) $-\ .350\ 3$
(13) $-\ .212\ 4$	(28) $-\ .271\ 4$	(43) $-\ .057\ 5$	(58) $-\ .432\ 3$
(14) $-\ .300\ 6$	(29) $-\ .257\ 7$	(44) $-\ .119\ 6$	(59) $+\ .381\ 1$
(15) $=-0.231\ 4$	(30) $=+0.378\ 9$	(45) $=-0.301\ 9$	(60) $=+0.051\ 2$

Check: $\Sigma pvv=+5.964\ 3$ $\qquad \Sigma+\text{corrections}=7.701\ 1$

$-\Sigma\omega C=+5.963\ 8$ $\qquad \Sigma-\text{corrections}=7.701\ 4$

Letting n stand for the number of conditions we have—

Mean error of an observed *direction* $\quad m_1=\sqrt{\frac{[pvv]}{n}}=\pm0''.43$

Mean error of an *angle* $\quad m_\angle=m_1\sqrt{2}\quad=\pm0''.61$, also

Probable error of an angle $\quad=\pm0''.41$

TRIANGLES OF THE OLNEY BASE NET, ILLINOIS, 1879, 1883–84.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Logarithms.	Distances in metres.
		°	′	″	″	″	″		
1	Buffalo Mound	71	13	07 ·72	−0 ·34	07 ·38	0 ·03	3 ·818 936 8	6 590 ·780
	Olney East Base	61	00	51 ·89	−0 ·06	51 ·83	0 ·03	3 ·784 579 2	6 089 ·47
	Olney West Base	47	46	00 ·53	+0 ·34	00 ·87	0 ·02	3 ·712 175 5	5 154 ·37
				00 ·14			0 ·08		
2	Olney Middle Base	100	04	09 ·23	+0 ·81	10 ·04	0 ·01	3 ·784 579 2	6 089 ·47
	Olney West Base	47	46	03 ·17	+0 ·70	03 ·87	0 ·01	3 ·660 802 7	4 579 ·34
	Buffalo Mound	32	09	46 ·11	+0 ·02	46 ·13	0 ·02	3 ·517 499 3	3 292 ·30
				58 ·51			0 ·04		
3	Olney Middle Base	79	55	44 ·29	−0 ·33	43 ·96	0 ·01	3 ·712 175 5	5 154 ·37
	Buffalo Mound	39	03	21 ·61	−0 ·36	21 ·25	0 ·01	3 ·518 313 9	3 298 ·48
	Olney East Base	61	00	54 ·85	−0 ·02	54 ·83	0 ·02	3 ·660 802 6	4 579 ·34
				00 ·75			0 ·04		
4	Check Base	33	46	43 ·71	−0 ·32	43 ·39	0 ·04	3 ·784 579 2	6 089 ·47
	Olney West Base	94	31	34 ·71	+0 ·59	35 ·30	0 ·05	4 ·038 158 0	10 918 ·37
	Buffalo Mound	51	41	41 ·79	−0 ·35	41 ·44	0 ·04	3 ·934 229 7	8 594 ·68
				00 ·21			0 ·13		
5	Check Base	49	38	45 ·09	+0 ·10	45 ·19	0 ·03	3 ·818 936 8	6 590 ·780
	Olney West Base	46	45	34 ·18	+0 ·25	34 ·43	0 ·04	3 ·799 370 1	6 300 ·43
	Olney East Base	83	35	40 ·89	−0 ·41	40 ·48	0 ·03	3 ·934 229 7	8 594 ·68
				00 ·16			0 ·10		
6	Check Base	15	52	01 ·38	+0 ·42	01 ·80	0 ·02	3 ·712 175 5	5 154 ·37
	Buffalo Mound	19	31	25 ·93	+0 ·01	25 ·94	0 ·02	3 ·799 370 1	6 300 ·43
	Olney East Base	144	36	32 ·78	−0 ·47	32 ·31	0 ·01	4 ·038 158 0	10 918 ·37
				00 ·09			0 ·05		
7	Onion Hill	4	40	27 ·96	−0 ·30	27 ·66	0 ·01	3 ·784 579 2	6 089 ·47
	Buffalo Mound	6	07	45 ·67	+0 ·42	46 ·09	0 ·00	3 ·901 934 2	7 978 ·74
	Olney West Base	169	11	45 ·96	+0 ·31	46 ·27	0 ·01	4 ·146 340 6	14 006 ·85
				59 ·59			0 ·02		
8	Onion Hill	21	19	56 ·39	−0 ·56	55 ·83	0 ·06	3 ·712 175 5	5 154 ·37
	Buffalo Mound	77	20	53 ·39	+0 ·08	53 ·47	0 ·06	4 ·140 668 5	13 825 ·11
	Olney East Base	81	19	11 ·35	−0 ·47	10 ·88	0 ·06	4 ·146 340 5	14 006 ·85
				01 ·13			0 ·18		
9	Onion Hill	48	26	34 ·48	+0 ·27	34 ·75	0 ·11	4 ·038 158 0	10 918 ·37
	Buffalo Mound	57	49	27 ·46	+0 ·08	27 ·54	0 ·11	4 ·091 670 2	12 350 ·09
	Check Base	73	43	58 ·27	−0 ·23	58 ·04	0 ·11	4 ·146 340 4	14 006 ·85
				00 ·21			0 ·33		

TRIANGLES OF THE OLNEY BASE NET, ILLINOIS, 1879, 1883–84—continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Logarithms.	Distances in metres.
		°	′	″	″	″	″		
10	Onion Hill	16	39	28·43	−0·26	28·17	0·02	3·818 936 8	6 590·780
	Olney West Base	143	02	13·51	−0·65	12·86	0·03	4·140 668 5	13 825·11
	Olney East Base	20	18	19·46	−0·41	19·05	0·03	3·901 934 0	7 978·73
				01·40			0·08		
11	Onion Hill	43	46	06·52	+0·57	07·09	0·06	3·934 229 7	8 594·68
	Olney West Base	96	16	39·33	−0·90	38·43	0·06	4·091 670 2	12 350·09
	Check Base	39	57	14·56	+0·09	14·65	0·05	3·901 934 0	7 978·73
				00·41			0·17		
12	Onion Hill	27	06	38·09	+0·83	38·92	0·07	3·799 370 1	6 300·43
	Olney East Base	63	17	21·43	0·00	21·43	0·06	4·091 670 3	12 350·09
	Check Base	89	35	59·65	+0·20	59·85	0·07	4·140 668 5	13 825·11
				59·17			0·20		
13	Claremont	28	12	13·66	−0·29	13·37	0·10	3·901 934 1	7 978·74
	Onion Hill	60	53	55·11	+0·16	55·27	0·10	4·168 826 0	14 751·15
	Olney West Base	90	53	52·30	−0·64	51·66	0·10	4·227 380 2	16 880·30
				01·07			0·30		
14	Claremont	35	36	55·68	−0·09	55·59	0·05	4·091 670 2	12 350·09
	Onion Hill	17	07	48·59	−0·42	48·17	0·05	3·795 638 4	6 246·52
	Check Base	127	15	17·17	−0·77	16·40	0·06	4·227 380 2	16 880·30
				01·44			0·16		
15	Claremont	48	59	42·76	−0·18	42·58	0·18	4·146 340 5	14 006·85
	Onion Hill	65	34	23·07	−0·14	22·93	0·19	4·227 867 4	16 899·25
	Buffalo Mound	65	25	55·23	−0·19	55·04	0·18	4·227 380 1	16 880·30
				01·06			0·55		
16	Claremont	54	07	29·11	−0·11	29·00	0·14	4·140 668 5	13 825·11
	Onion Hill	44	14	26·68	+0·41	27·09	0·13	4·075 679 3	11 903·63
	Olney East Base	81	38	03·54	+0·78	04·32	0·14	4·227 380 1	16 880·30
				59·33			0·41		
17	Claremont	7	24	42·02	+0·19	42·21	0·01	3·934 229 7	8 594·68
	Olney West Base	5	22	47·03	−0·26	46·77	0·01	3·795 638 7	6 246·53
	Check Base	167	12	31·73	−0·68	31·05	0·01	4·168 826 1	14 751·16
				00·78			0·03		
18	Claremont	20	47	29·10	+0·11	29·21	0·07	3·784 579 2	6 089·47
	Olney West Base	99	54	21·74	+0·33	22·07	0·08	4·227 867 5	16 899·25
	Buffalo Mound	59	18	09·56	−0·62	08·94	0·07	4·168 826 0	14 751·15
				00·40			0·22		

TRIANGLES OF THE OLNEY BASE NET, ILLINOIS, 1879, 1883–84—continued.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Logarithms.	Distances in metres.
19	Claremont	25	55	15.45	+0.18	15.63	0.07	3.818 936 8	6 590.780
	Olney West Base	52	08	21.21	−0.02	21.19	0.06	4.075 679 4	11 903.63
	Olney East Base	101	56	23.00	+0.37	23.37	0.06	4.168 826 0	14 751.15
				59.66			0.19		
20	Claremont	13	22	47.08	−0.09	46.99	0.02	4.038 158 0	10 918.37
	Check Base	159	00	44.56	+1.00	45.56	0.02	4.227 867 4	16 899.25
	Buffalo Mound	7	36	27.77	−0.26	27.51	0.02	3.795 638 7	6 246.53
				59.41			0.06		
21	Claremont	18	30	33.43	−0.02	33.41	0.02	3.799 370 1	6 300.43
	Check Base	143	08	43.18	+0.58	43.76	0.02	4.075 679 4	11 903.63
	Olney East Base	18	20	42.11	+0.78	42.89	0.02	3.795 638 3	6 246.52
				58.72			0.06		
22	Claremont	5	07	46.35	+0.07	46.42	0.02	3.712 175 5	5 154.37
	Buffalo Mound	11	54	58.16	+0.27	58.43	0.01	4.075 679 4	11 903.63
	Olney East Base	162	57	14.89	+0.31	15.20	0.02	4.227 867 5	16 899.25
				59.40			0.05		
23	Detiver	9	09	24.76	−0.25	24.51	0.01	4.146 340 5	14 006.85
	Onion Hill	166	59	12.21	−0.56	11.65	0.02	4.297 098 3	19 819.75
	Buffalo Mound	3	51	24.10	−0.21	23.89	0.02	3.772 326 8	5 920.07
				01.07			0.05		
24	Denver	10	09	51.06	−0.28	50.78	0.01	3.901 934 1	7 978.74
	Onion Hill	162	18	44.25	−0.27	43.98	0.01	4.137 898 6	13 737.21
	Olney West Base	7	31	26.04	−0.76	25.28	0.02	3.772 327 0	5 920.07
				01.35			0.04		
25	Denver	60	45	57.44	−0.53	56.91	0.08	4.227 380 2	16 880.30
	Onion Hill	101	24	49.14	−0.42	48.72	0.09	4.277 875 3	18 961.62
	Claremont	17	49	15.39	−0.77	14.62	0.08	3.772 327 0	5 920.07
				01.97			0.25		
26	Denver	1	00	26.30	−0.036	26.264	0.004	3.784 579 2	6 089.47
	Buffalo Mound	2	16	21.57	+0.634	22.204	0.004	4.137 898 8	13 737.22
	Olney West Base	176	43	12.00	−0.456	11.544	0.004	4.297 098 1	19 819.75
				59.87			0.012		
27	Denver	51	36	32.68	−0.28	32.40	0.25	4.227 867 5	16 899.25
	Buffalo Mound	61	34	31.13	+0.02	31.15	0.25	4.277 875 4	18 961.62
	Claremont	66	48	58.15	−0.95	57.20	0.25	4.297 098 5	19 819.76
				01.96			0.75		

TRIANGLES OF THE OLNEY BASE NET, ILLINOIS, 1879, 1883-84—continued.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Logarithms.	Distances in metres.
28	Denver	50	36	06·38	−0·25	06·13	0·17	4·168 826 0	14 751·15
	Olney West Base	83	22	26·26	+0·13	26·39	0·17	4·277 875 3	18 961·62
	Claremont	46	01	29·05	−1·06	27·99	0·17	4·137 898 5	13 737·21
				01·69			0·51		
29	Newton	52	21	59·17	+0·19	59·36	0·28	4·277 875 3	18 961·62
	Claremont	46	54	49·55	−0·66	48·89	0·28	4·242 702 7	17 486·49
	Denver	80	43	13·71	−1·13	12·58	0·27	4·373 466 1	23 630·13
				02·43			0·83		
30	Hunt City	14	03	41·72	−0·06	41·66	0·13	4·227 867 5	16 899·25
	Claremont	15	27	52·31	+0·86	53·17	0·13	4·268 259 5	18 546·39
	Buffalo Mound	150	28	24·58	+0·98	25·56	0·13	4·535 016 4	34 278·07
				58·61			0·39		
31	Hunt City	42	20	35·00	+0·14	35·14	0·40	4·373 466 1	23 630·13
	Claremont	35	22	00·91	+0·56	01·47	0·40	4·307 622 1	20 305·89
	Newton	102	17	25·36	−0·78	24·58	0·39	4·535 016 5	34 278·08
				01·27			1·19		
32	Oblong	34	36	31·20	−0·75	30·45	0·26	4·227 867 5	16 899·25
	Claremont	39	43	53·41	+0·37	53·78	0·26	4·279 177 2	19 018·54
	Buffalo Mound	105	39	36·26	+0·29	36·55	0·26	4·457 118 7	28 649·61
				00·87			0·78		
33	Oblong	100	27	20·78	−0·35	20·43	0·34	4·535 016 4	34 278·07
	Claremont	24	16	01·10	−0·48	00·62	0·34	4·156 114 3	14 325·65
	Hunt City	55	16	40·16	−0·19	39·97	0·34	4·457 118 7	28 649·61
				02·04			1·02		
34	Oblong	65	50	49·58	+0·40	49·98	0·21	4·268 259 5	18 546·39
	Buffalo Mound	44	48	48·32	+0·69	49·01	0·21	4·156 114 2	14 325·65
	Hunt City	69	20	21·88	−0·24	21·64	0·21	4·279 177 2	19 018·54
				59·78			0·63		

PROBABLE ERRORS.

Determination of the probable errors of the length of the sides common to the net and to the adjacent chains of triangulation.

For the side Hunt City to Oblong, as adjusted, we make use of the expression

$$\frac{\text{Hunt City to Oblong}}{\text{Olney Base}} = \frac{\sin(43-39)\sin(49-45)\sin(17-14)\sin(33-32)}{\sin(15-11)\sin(29-26)\sin(23-22)\sin(20-18)};$$

hence the function—

$$F = \log\sin(43-49) + \log\sin(49-45) + \log\sin(17-14) + \log\sin(33-32)$$
$$-\log\sin(15-11) - \log\sin(29-26) - \log\sin(23-22) - \log\sin(20-18).$$

Establishing and solving the transfer equations, we find the reciprocal of the weight $\frac{1}{P} = 26{\cdot}615$, also the mean error m_F, and the probable error r_F, both expressed in units of the sixth place of decimals in the logarithm, viz, $\pm 2{\cdot}227$ and $\pm 1{\cdot}502$, respectively; hence log distance Hunt City to Oblong $4{\cdot}156\ 114\ 2$ $\pm 1\ 5$ and the distance $14\ 325{\cdot}65$ $\pm 0{\cdot}05$ metres. The probable error is about $\frac{1}{287\ 000}$ part of the length.

To this must be added the proportional error depending upon that of the base measure, or $\pm 0{\cdot}0089 \times \frac{14\ 326}{6\ 591} = \pm 0{\cdot}019$ metre; hence probable error of length of side Hunt City to Oblong, $\sqrt{(0{\cdot}05)^2 + (0{\cdot}019)^2} = \pm 0{\cdot}05$ metre.

For the side Hunt City to Newton, we use the expression

$$\frac{\text{Hunt City to Newton}}{\text{Olney Base}} = \frac{\sin(43-39)\sin(50-49)\sin(8-4)\sin(16-12)}{\sin(15-11)\sin(\ 8-7\ )\sin(3-2)\sin(21-19)}$$

$$F = \log\sin(43-39) + \log\sin(50-49) + \log\sin(8-4) + \log\sin(16-12)$$
$$-\log\sin(15-11) - \log\sin(\ 8-7\ ) - \log\sin(3-2) - \log\sin(21-19)$$

Establishing and solving the transfer equations, we get

$$\frac{1}{P} = 20{\cdot}859, \text{ also } m_F = \pm 1{\cdot}97 \text{ and } r_F = \pm 1{\cdot}33; \text{ hence}$$

log. distance Hunt City to Newton $= 4{\cdot}307\ 622\ 1$ $\pm 1\ 3$ and distance $= 20\ 305{\cdot}89$ $\pm 0{\cdot}06$ metres. The probable error is about $\frac{1}{327\ 000}$ part of the length; adding to this the proportional error arising from the base measure, or $\pm 0{\cdot}0089 \times \frac{20\ 306}{6\ 591} = \pm 0{\cdot}028$ metre, the probable error of length of side Hunt City to Newton is $\sqrt{(0.06)^2 + (0{\cdot}028)^2} = \pm 0{\cdot}07$ metre.

We may also take without sensible error the probable error of the side Hunt City to Claremont as $\frac{1}{306\ 000}$ part, or $\pm 0{\cdot}112$, to which error must be added that proportional one due to the base measure, or $\pm 0{\cdot}0089 \times \frac{34\ 278}{6\ 591} = \pm 0{\cdot}046$; hence probable error of side Hunt City to Claremont $= \pm 0{\cdot}12$ metre.

GENERAL DESCRIPTION OF STATIONS FORMING THE OLNEY BASE NET, ILLINOIS.

East Base, Jasper County, Illinois; established in 1879 by the United States Lake Survey. This station, marking the east end of the Olney Base Line, is situated in section 19, township 5 north, fractional range 11 east, St. Marie Township, about 3½ miles east and one-half mile north of the railway station of West Liberty, on the Grayville and Mattoon Railroad. The geodetic point is marked by a brass cylinder leaded into the top of a stone post of the usual form, set 2½ feet below the surface of the ground, and surrounded by brickwork 3 feet square and 3 feet deep. Two side stones are set on a line at right angles to the direction of the base line, and at a depth below the surface of the ground of about 2½ feet; one bears north 1° 28′ west, distant 7·91 metres, and the other south 1° 28′ east, distant 8·04 metres from the geodetic point.* Three stone reference posts are set as follows: One bearing north 49° 49′ east, distant 361 metres; one bearing south 58° 02′ east, distant 322 metres, and one bearing south 35° 50′ west, distant 208 metres from the geodetic point. The northwest corner of section 19, township 5 north, fractional range 11 east, bears north 77° 12′ west, and is distant about 1 054 metres from the geodetic point.

West Base, Jasper County, Illinois; established in 1879 by the United States Lake Survey. This station, marking the west end of the Olney Base Line, is situated in the northwest quarter of the northeast quarter of section 21, township 5 north, range 10 east, Fox Township. The geodetic point is marked by a stone post of the usual form, set in a bed of brickwork 3 feet square, with its top 4 feet below the surface of the ground. Two additional stones are set on a line through the geodetic point perpendicular to the direction of the base line and at a depth below the surface of the ground of about 4 feet, one bearing north 1° 30′ west, distant 8·02 metres, and one bearing south 1° 30′ east, distant 8·06 metres from the geodetic point. Three stone reference posts are set as follows: Two on the south side of the road north of the station, one bearing north 2° 45′ west, distant 246·7 metres, and one bearing north 45° 32′ east, distant 356·0 metres, and one bearing south 61° 00′ east, distant 302·0 metres. An oak latitude post 17 inches in diameter, occupied in 1880, bears south 88° 36′ east, and is distant 16·19 metres. The northeast corner of section 21 bears north 67° 19′ east, and is distant about 727 metres.

Buffalo Mound, Jasper County, Illinois; established in 1879 by the United States Lake Survey. This station is situated in section 1, near the line between sections 1 and 2, township 5 north, range 10 east, of the third principal meridian, Fox Township, on a hill known as Buffalo Mound, about 2½ miles southwest of the village of St. Marie. The geodetic point is marked in the usual manner by two stone posts set one above the other. Three stone reference posts are set on the west side of the section-line road just west of the station, as follows: One bearing south 40° 46′ west, distant 44.4 metres; one bearing north 87° 19′ west, distant 28·9 metres, and one bearing north 38° 54′ west, distant 45·3 metres. The corner of sections 1, 2, 11, and 12 bears south 1° 29′ west, and is distant 966 metres from the geodetic point.

Middle Base, Jasper County, Illinois; established in 1879 by the United States Lake Survey. This station, near the middle of the Olney Base Line, is situated in the northwest quarter of section 23, township 5 north, range 10 east, Fox Township, about 1·1

* All bearings in the Olney Base Net are true.

miles east and one-half mile north of West Liberty, a station on the Grayville and Mattoon Railroad. The geodetic point is marked by a stone post of the usual form, set 2½ feet below the surface. The northeast corner of section 23 bears north 66° 18′ east, and is distant about 712 metres from the geodetic point.

Check Base, Richland County, Illinois; established in 1879 by the United States Lake Survey. This station is situated in section 6, township 4 north, range 11 east, Preston Township. The geodetic point is marked by a hole in the top of a stone post set 2½ feet below the surface of the ground, with a stone post set directly over it as a surface mark. Three stone reference posts are set as follows: One on the south side of the road on the south of the station, bearing south 12° 12′ west, distant 22·6 metres; one at the northeast corner of the cemetery just west of the station, bearing north 3° 35′ west, distant 73 metres, and one on the north side of the above road, bearing south 80° 21′ east, distant 53·5 metres. The southeast corner of the German Reformed Church bears north 53° 10′ west, and is distant 20·1 metres. The quarter-section stone of the west line of section 6 bears north 31° 44′ west, and is distant 943·9 metres from the geodetic point.

Onion Hill, Richland County, Illinois; established in 1879 by the United States Lake Survey. This station is situated in the northeast quarter of section 2, township 4 north, range 9 east, Denver Township, about 5 miles southwest of West Liberty, a station on the Grayville and Mattoon Railway, on Onion Hill. The geodetic point is marked by a stone post of the usual form set 3 feet below the surface, with a stone post set directly over it as a surface mark. Three stone reference posts were set as follows: One on the south side of the road north of the station, bearing north 33° 02′ east, distant 205·68 metres; one on the north side of the same road, bearing north 25° 31′ west, distant 181·04 metres, and one on the west side of the road west of the station, bearing north 84° 35′ west, distant 354·02 metres from the geodetic point. The northeast corner of section 2 bears north 69° 25′ east, and is distant 502·7 metres from the geodetic point.

Claremont, Richland County, Illinois; established in 1879 by the United States Lake Survey. This station is situated in section 29, township 4 north, range 14 west, German Township, about 3 miles northwesterly from the town of Claremont, a station on the Ohio and Mississippi Railroad, on land belonging to the Brinkley heirs. The geodetic point is marked by two stone posts set one above the other, in the usual manner. Three stone reference posts are set as follows: One bearing north 67° 33′ west, distant 23·1 metres; one bearing north 0° 39′ west, distant 7·8 metres, and one bearing north 71° 45′ east, distant 24·6 metres from the geodetic point. The northwest corner of section 29 bears north 60° 03′ west, and is distant 847 metres from the geodetic point.

Denver, Richland County, Illinois; established in 1879 by the United States Lake Survey. This station is situated in the northwest quarter of the northeast quarter of section 21, township 4 north, range 9 east, Denver Township, about 5½ miles north of station Noble on the Ohio and Mississippi Railroad, on land belonging to Mr. Kinkade, living a little more than one-fourth mile east of the station. The geodetic point is marked by a stone post of the usual form set 3 feet below the surface of the ground, with a stone post set directly over it as a surface mark.

Three stone reference posts were set as follows: One on the north side of the road north of the station, bearing north 15° 27′ east, distant 344·92 metres; one on the east side of the road east of the station, bearing north 69° 35′ east, distant 578·78 metres;

and one on the west side of the latter road, bearing south 70° 01′ east, and distant 568·15 metres from the geodetic point.

The corner of sections 15, 16, 21, and 22 bears north 58° 52′ east and is distant 628·32 metres.

Newton, Jasper County, Illinois; established by F. W. Perkins in 1883. This station is situated near the northwest corner of the southeast quarter of the southwest quarter of section 25, township 6 north, range 9 east, Smallwood Township, about 4½ miles south of Newton, the county seat. The geodetic point is marked by the apex of an earthenware pyramid set in mortar 3½ feet below the surface. The surface mark is the intersection of two cross lines cut on top of a white marble post, 6 inches square and 2½ feet long, projecting 6 inches above the surface. The letters U.S.C.&G.S. are cut in the 4 squares formed by the cross lines. This post stands on a brick foundation 1 foot thick and 16½ inches square and is solidly encased in brick to its top. From this point up, a height of 3 feet, the brick pier is hollow and is capped by a marble slab 2 inches thick and 16½ inches square, with a small hole in the center to mark the station. At the top of the marble post openings were left in the brickwork in order that the cross lines on the post could be seen. The whole height of the brick pier is 6½ feet. Another brick pier 21 by 16½ inches, used for latitude observations, was built about 50 feet distant due west. Two marble posts 5 inches square and 2¼ feet long, with arrows on top pointing to the station, were set as reference posts, nearly west and in range, one 221·4 feet and the other 1 508·8 feet distant, bearing (true) south 89° 59′ west from the station. The following true bearings and distances were measured from the geodetic point: East lightning rod of I. Wilson's house south 9° 13′ west southwest corner of section 25, south 50° 59′ west 607·4 metres distant. Chimney of McMurray's house north 54° 26′ west. Chimney of schoolhouse north 46° 20′ west. Chimney of Weaver's house north 22° 33′ west 1 180·3 metres distant. Southeast corner of section 25, south 71° 50′ east 1 217·6 metres distant.

Hunt City, Jasper County, Illinois; established in 1879 by the United States Lake Survey. This station is situated in the northeast quarter of the northwest quarter of section 7, township 7 north, range 14 west, Grandville Township, about 10 miles northeast of Newton, and about three-fourths mile northeast of Hunt City, a small station on the Danville, Olney and Ohio River Railroad. The geodetic point was marked by a stone post of the usual form, set 3 feet below the surface, with a stone post set directly over it as a surface mark. Three stone reference posts were set as follows: Two on the south side of the section-line road north of the station, one bearing north 33° 52′ east, distant 334·71 metres, and one bearing north 9° 54′ west, distant 282·62 metres; and one on the east side of the section-line road west of the station, bearing south 85° 32′ west, and distant 678·88 metres from the geodetic point. The section corner at the northwest corner of section 7 and southwest corner of section 6 (above township) bears north 66° 46′ west, and is distant 749·0 metres. The section corner at the southeast corner of section 6 and the northeast corner of section 7, township 7 north, fractional range 11 east, bears north 67° 05′ west, and is distant 747·0 metres from the geodetic point. These two section corners are 4·56 metres apart.

Oblong, Crawford County, Illinois; established in 1879 by the United States Lake Survey. This station is situated in the southeast quarter of the southeast quarter of section 32, township 7 north, range 13 west, Oblong Township. The geodetic point is

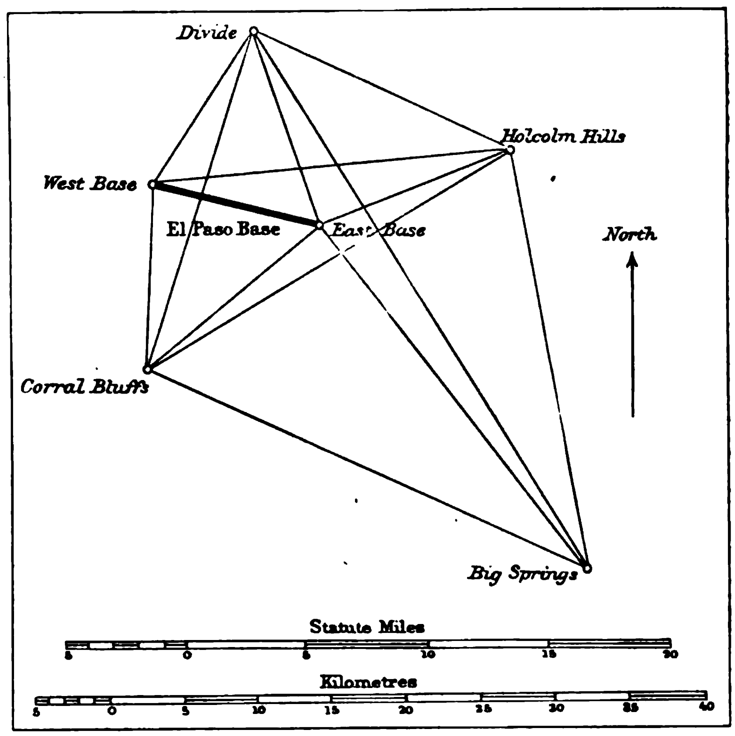
marked in the usual manner by two stone posts set one above the other. Three stone reference posts are set along the east side of the road west of the station as follows: One bearing south 44° 15′ west, distant 125·7 metres; one bearing south 78° 32′ west, distant 90·0 metres, and one bearing north 65° 13′ west, distant 97·7 metres from the geodetic point. The first reference post mentioned is set near the land-survey stone on the south line of section 32, one-fourth mile west of the southeast corner of the section, the land-survey stone bearing south 46° 23′ west, and being distant 131 metres from the geodetic point. The southeast corner of section 32 bears south 73° 42′ east, and is distant 325·6 metres from the geodetic point.

(*d*) *El Paso Base Line, Colorado, 1879.*

LOCATION, MEASUREMENT, AND LENGTH.

This base is located on the eastern slope of the Rocky Mountains, in El Paso County, Colorado. A reconnaissance made by O. H. Tittmann, Assistant, Coast and Geodetic Survey, in August, 1878, resulted in the selection of the site about 48 kilometres (30 statute miles) east northeast of Pikes Peak, with the middle point in approximate latitude 38° 58′ and longitude 104° 31′ west, and about 2 063 metres (6 768 feet) above the sea level. It is the most elevated base line on the arc. The length is approximately 11·29 kilometres (7·02 statute miles) and the azimuth East Base to West Base about 102°·8. The line is on the table land south of the divide between the valleys of Monument and Bracket creeks, with a general slope of the ground upward from east to west, the western terminus being nearly 172 metres above the eastern one, as determined by two lines of spirit levels. The line was free of all obstructions, such as trees, shrubs, fences, or buildings, and required no grading whatever; the ground was dry, gravelly, and sandy and covered with a short growth of grass. The line crosses the dry bed of Squirrel Creek and a few gulches and running springs. A masonry monument on the Townsend Ranch marks the east end, another like it on the old Pugsley Ranch the west end. The underground marks are two granite posts, set in cement and one above

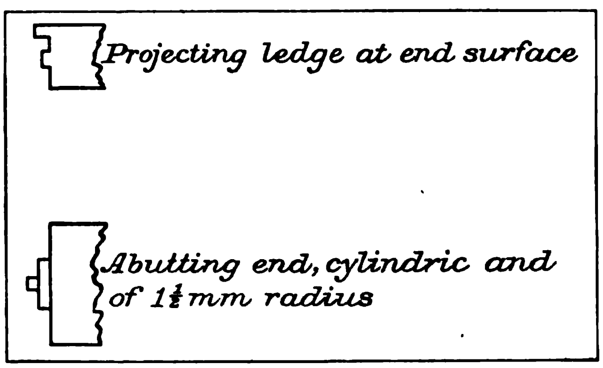
No. 7.



the other. Each has a hole drilled in its upper surface, filled with lead with a copper tack driven into it; a line drawn on the head of the tack marks the terminal point of the base. The monuments are of brick, about a metre high, and capped with a stone slab 15 centimetres (6 inches) thick.

A preliminary measure was made with a 60-metre steel chain, and stubs were placed in alignment subdividing the line into 54 sections. The base was measured twice, once forward and once backward, by Assistant Tittmann, with the 6-metre contact-slide steel rods Nos. 3 and 4, between August 7 and September 4, 1879. This apparatus was made by E. Kübel, of Washington, District of Columbia, in June, 1878, and was employed here for the first time. A description of this kind of apparatus will be found in Appendix No. 17, Coast and Geodetic Survey Report for 1880, pp. 341–345. It embodies the principle and construction of Colonel Mudge's apparatus,* but received great improvements in the hands of Assistant J. E. Hilgard, as stated by him in the above appendix.

No. 6.



Length of the contact-slide rods Nos. 3 and 4.—These rods are agate-capped and about 8 millimetres in diameter. They were compared at the Survey Office with the standard iron 6-metre bar No. 1, by Assistants H. G. Ogden and O. H. Tittmann, in May, 1879, and again after the return of the rods from the base measure by Assistants Ogden and S. Forney in November, 1879. The 6-meter standard bar No. 1 dates from March, 1847, and was made for standardizing the Bache-Würdemann compensation base apparatus, last used in 1873. The length of this end standard† was determined at various times, in 1847 by J. Saxton and A. A. Humphreys, in 1853–54 by J. Saxton, in 1860 by J. E. Hilgard and W. L. Nicholson, and in 1877 by H. W. Blair. These last comparisons are dependent on six new steel metres specially constructed for the purpose, and being the most elaborate and nearest in time to the base measure, their result alone is given here. Extensive observations were made at the Smithsonian Institution between February and April, 1860, for the determination of the coefficient of expansion. For an account of these observations, as well as of the standardizing of the bar, see the description given by Assistant Hilgard in Appendix No. 26, Coast Survey Report for 1862. The range of temperature during these observations was between 0° and 38° C. (32 to 100° F.), with resulting coefficient of expansion 0·000 011 54 ± 4 for the centigrade scale (0·000 006 41 ± 2 for the Fahrenheit scale). The observations of February and March, 1877, for length of 6-metre standard, consist in the first place of comparisons of the 6 steel-end ‡ metre bars (Nos. 1, 12, 13, 19, 28, 35) *inter se*, and of No. 19 with the

* Triangulation of England and Wales, etc. Vol. I, London, 1799, plate iv.
† Projecting ledge at end surface. (See above cut.)
‡ Abutting end cylindric and of 1½ millimetres radius. (See above cut.)

Committee Metre; and, secondly, of comparisons of length of the 6 metres joined, contacts secured by springs, aligned, leveled, and duly supported with the 6-metre bar. In these comparisons several thermometers were used. They were properly distributed and corrected for index error and defect in graduation, besides the *relative* positions of the various bars were systematically changed; the average temperature was about 7½° C. (45½° F.). Saxton's reflecting comparator (called pyrometer) was used for the differential measures. At the same time a copy of the 6-metre standard, known as No. 2,* cut to length in February, 1855, was standardized in the same manner and compared with No. 1; it was found to be $24{\cdot}7\mu$ (microns) longer than No. 1 (both at $5^\circ{\cdot}1$ C.). The comparisons of 1860 give the result: Length of the 6-metre iron standard No. 1 = $5^{\text{m}}{\cdot}999\ 940\ 7 \pm 8$ at 0°C.

and of No. 2 = $5^{\text{m}}{\cdot}999\ 982\ 3 \pm 1\ 0$ at 0°C.

From the comparisons of 1877 the following results† have been deduced:

Length of 6-metre iron standard No. 1 = $5^{\text{m}}{\cdot}999\ 954\ 7 \pm 2\ 5$ at 0° C.

Length of 6-metre iron standard No. 2 = $5^{\text{m}}{\cdot}999\ 982\ 6 \pm 1\ 0$ at 0° C.

An additional value for length of standard No. 1 is obtained from comparisons made by Assistant C. A. Schott in August and September, 1882, at the Survey Office in connection with the standardizing of a 5-metre standard to which was joined a single-metre bar, both of known length,‡ whence we have length of 6-metre standard No. 1 $5^{\text{m}}{\cdot}999\ 946\ 1 \pm 4\ 6$ at 0° C. For final value of length of this standard we take the weighted mean of the three values of 1860, 1877, and 1882 with their weights ½, 1, and ½, respectively, and find length of standard No. 1 = $5^{\text{m}}{\cdot}999\ 949 \pm 3$ at 0° C. Comparisons made in May and November, 1879, of the 6-metre contact-slide rods Nos. 3 and 4 with standard No. 1 gave the following results:

May 17 and 18, 1879. H. G. Ogden and O. H. Tittman, observers.

Length of No. 3 = $6^{\text{m}}{\cdot}001\ 076 \pm 5$ at $17^\circ{\cdot}28$ C.

Length of No. 4 = $6^{\text{m}}{\cdot}001\ 142 \pm 4$ at $17^\circ{\cdot}28$ C.

November 26 and 28, 1879. H. G. Ogden and S. Forney, observers.

Length of No. 3 = $6^{\text{m}}{\cdot}000\ 514 \pm 4$ at $7^\circ{\cdot}74$ C.

Length of No. 4 = $6^{\text{m}}{\cdot}000\ 476 \pm 4$ at $7^\circ{\cdot}74$ C.

* An end measure without projecting edge.

† The observer's result was: Length of standard, $5{\cdot}999\ 958\ 3 \pm 7$ metres at 0° C.; but a discussion of March, 1883, gave the result in the text.

‡ Appendix No. 7, Coast and Geodetic Survey Report for 1882, pp. 137–138.

In the absence of a reliable value for the coefficient of expansion of these rods, it was decided to have special observations made. Under date of March 27, 1897, Assistant A. Braid, in charge of Weights and Measures, reports the results of his observations as follows:

Observations in March, 1897.	For 6-metre standard No. 2	0·000 011 25 for the C. scale
	For 6-metre bar No. 3	0·000 011 49
	For 6-metre bar No. 4	0·000 011 41

Hence we have:

Length of No. 3 at 12°·51 C. (or 54°·52 F.) 6·000 795 metres, or at 0° C. 5·999 933 metres
Length of No. 4 at 12°·51 C. (or 54°·52 F.) 6·000 809 metres, or at 0° C. 5·999 953 metres

The probable error of each may be estimated at $\pm 6\mu$. The corrections to the graduation of the Tagliabue thermometers attached to the rods were determined by means of a Casella standard No. 18411. They are as follows:

Thermometers.

Correction at	Rod No. 3. 502	Rod No. 4. 503
°	°	°
92 F.	−0·6	−0·5
82	−0·6	−0·5
62	−0·5	−0·4
45	−0·7	−0·4

For the purpose of comparing the results by the forward and backward measures, or those of the day and night measure, the agate end of the rods was referred to the ground by means of a sector (with level attached) set at right angles to the length of the base. A short distance away and opposite to it, at the ground mark, an ivory scale divided into millimetres was read off.

In the following summary of resulting lengths of the forward and backward measures the distances are corrected for errors arising from temperature, inclination and alignment of the bars, but no reduction to sea level has been applied.

Section measures of the El Paso Base.

Section marks.	Mean temp. F. corr'd. Forward.	Mean temp. F. corr'd. Backward.	No. of (average) bars.	Corrected distance, forward.	Corrected distance, backward.	Mean.	Difference from mean.
	°	°		m.	m.	m.	mm.
East Base to A (day)	57·41			240·014 50			1·39
(night)	57·38		40	·013 09		240·013 11	0·02
(night)	59·79			·011 74			1·37
A to B (day)	60·76			198·023 56			0·26
B to A (day)		68·37	33		198·025 33	198·023 82	1·51
A to B (night)	51·11			198·022 57			1·25
B to C (day)	66·45			222·033 68			1·60
C to B (day)		70·09	37		222·033 85	222·032 08	1·76
B to C (night)	49·29			222·028 72			3·36

Section measures of the El Paso Base—Continued.

Section marks.	Mean temp. F. corr'd. For-ward.	Mean temp. F. corr'd. Back-ward.	No. of (average) bars.	Corrected distance, forward.	Corrected distance, backward.	Mean.	Differ-ence from mean.
	°	°		m.	m.	m.	mm.
C to D (day)	68·35			204·023 29			0·32
D to C (day)		66·96	34		204·025 71	204·023 61	2·10
C to D (night)	46·39			204·021 82			1·79
D to E	64·18	75·61	46	276·030 80	276·031 00	276·030 90	0·10
E to F	54·22	66·71	33	198·004 29	198·003 68	198·003 99	0·30
F to G	63·01	72·44	35	210·016 96	210·020 12	210·018 54	1·58
G to H	71·12	77·59	32	192·027 78	192·027 88	192·027 83	0·05
H to I	80·45	76·84	37	222·046 79	222·043 99	222·045 39	1·40
I to J	88·96	68·72	39	234·060 44	234·056 21	234·058 32	2·11
J to K	82·34	61·63	30	180·022 54	180·021 29	180·021 91	0·62
K to L	63·08	73·68	34	203·983 48	203·983 78	203·983 63	0·15
L to Ridge	74·47	83·44	36	215·974 32	215·977 16	215·975 74	1·42
Ridge to M	60·10	74·74	34	203·983 88	203·984 87	203·984 38	0·50
M to N	64·99	82·80	29	174·020 09	174·020 08	174·020 09	0·01
N to O	71·00	85·27	32	192·006 14	192·002 53	192·004 33	1·81
O to P	62·44	81·02	34	204·006 22	204·004 38	204·005 30	0·92
P to Q	58·20	76·99	34	203·976 90	203·977 06	203·976 98	0·08
Q to R	69·26	82·50	37	222·027 92	222·026 39	222·027 16	0·77
R to S	78·36	84·43	34	204·033 84	204·031 09	204·032 47	1·37
S to Signal	65·71	86·37	40	239·993 41	239·995 71	239·994 56	1·15
Signal to T	76·98	86·34	34	204·022 39	204·021 65	204·022 02	0·37
T to U	84·91	88·65	34	204·042 62	204·041 20	204·041 91	0·71
U to V	94·15	82·22	34	204·049 97	204·046 68	204·048 32	1·65
V to W	67·34	77·59	34	204·030 96	204·032 42	204·031 69	0·73
W to X	66·91	87·06	34	204·029 70	204·033 18	204·031 44	1·74
X to Y	75·15	84·87	34	204·011 04	204·011 62	204·011 33	0·29
Y to Z	82·47	81·43	34	204·041 71	204·040 92	204·041 32	0·40
Z to Gulch	87·16	77·20	31	186·054 94	186·055 22	186·055 08	0·14
Gulch to Range	61·91	69·70	44	264·005 55	264·008 99	264·007 27	1·72
Range to Dot	71·60	60·43	34	204·034 09	204·034 96	204·034 52	0·43
Dot to Spring	79·23	86·42	24	144·006 45	144·007 29	144·006 87	0·42
Spring to Road	89·39	82·30	33	198·017 23	198·018 03	198·017 63	0·40
Road to α	72·89	85·97	49	294·008 15	294·005 08	294·006 62	1·53
α to β	87·74	89·22	32	192·028 30	192·024 21	192·026 25	2·04
β to γ	67·33	80·81	37	222·004 64	222·004 68	222·004 66	0·02
γ to δ	81·18	84·83	32	192·038 81	192·036 36	192·037 58	1·23
δ to ε	88·18	87·22	35	210·025 44	210·022 97	210·024 20	1·23
ε to ζ	87·47	86·59	34	203·993 45	203·992 05	203·992 75	0·70
ζ to η	68·53	83·41	34	203·995 83	203·994 45	203·995 14	0·69
η to θ	76·06	82·01	35	210·029 95	210·028 66	210·029 31	0·64
θ to ι	83·31	78·00	35	210·037 34	210·035 46	210·036 40	0·94

Section measures of the El Paso Base—Continued.

Section marks.	Mean temp. F. corr'd. Forward.	Mean temp. F. corr'd. Backward.	No. of (average) bars.	Corrected distance forward.	Corrected distance. backward.	Mean.	Difference from mean.
	°	°		*m.*	*m.*	*m.*	*mm.*
ι to κ	60·29	73·60	34	203·987 39	203·988 55	203·987 97	0·58
κ to λ	66·83	66·87	35	209·977 26	209·978 42	209·977 84	0·58
λ to μ	74·57	56·61	41	246·033 64	246·033 64	246·033 64	0·00
μ to ν	65·18	91·09	28	167·945 30	167·944 47	167·944 88	0·41
ν to ξ	67·83	87·96	24	143·999 69	143·999 88	143·999 79	0·10
ξ to ο	75·54	79·20	40	239·967 06	239·965 39	239·966 23	0·83
ο to π	68·68	69·70	35	210·005 83	210·004 77	210·005 30	0·53
π to ρ	80·51	61·15	36	215·953 11	215·950 94	215·952 02	1·09
ρ to σ	85·41	53·60	34	203·985 44	203·984 31	203·984 88	0·56
σ to τ	85·84	48·28	36	215·978 09	215·976 83	215·977 46	0·63
τ to υ	80·77	78·41	29	173·974 49	173·973 61	173·974 05	0·44
υ to West Base	60·95			258·207 93			4·62
υ to West Base	61·62			258·215 12			2·57
			43			258·212 55	
West Base to υ		74·92			258·215 86		3·31
West Base to υ		85·08			258·211 27		1·27
East Base to West Base			1 882			11 292·823 09	

The forward and backward measures of the subdivisions were frequently made with greatly different average temperatures, yet when we compare their respective sums we find 11 292·833 1 metres and 11 292·815 7, showing the small difference of 17·4 millimetres.

The matter as to whether the thermometers indicate the true temperature of the rods has been inquired into, and it seemed as if the rods were lagging somewhat behind the thermometer indications, but there are so many exceptions to this that no satisfactory result (numerical value) could be deduced.

For the reduction of the length of the El Paso Base line to the sea level we have the following data and results:

The provisional value for height of the St. Louis, Missouri, bench mark is at present taken as 125·8 ± 0·25 metres or 412·7 ± 0·8 feet. This mark, known as the City Directrix, is identical in level with the bench mark K_3 on the St. Louis great bridge. They are referred to the mean level of the Gulf of Mexico (and probably also to the Atlantic Ocean at Sandy Hook, New Jersey, within the assigned probable error).

The difference of height between the St. Louis bench mark K_3 and top of base monument marking the west end of the El Paso Base, as derived from spirit leveling in 1882–88 and 1891–95–96–97–98, a distance of 1 437 kilometres nearly, is $\triangle h = 2\ 040·91 \pm 0·044$ metres or 6 695·89 ± 0·15 feet. Hence the height of West Base Monument (top*) above sea level is 2 166·7 ± 0·25 metres or 7 108·6 ± 0·8 feet. In August and September, 1879, J. B. Weir ran a line of spirit levels over the base and found the East

* Top above ground 1·05 metres.

Base Monument (top*) 172·14 metres or 564·76 feet below the West Base Monument, whence the height of East Base Monument (top) is 1 994·56 metres or 6 543·8 feet. From 10 equal subdivisions of the base its average height above the East Base Monument (top) was found to be 66·86 metres or 219·4 feet; hence the average height of base line is 2 061·4 metres or 6 763·1 feet. To the above height we must add the elevation of the base bars above ground or 1·25 metres (4·10 feet); hence the final result for height of base above sea level is $h = 2\ 062{\cdot}65$ metres or 6 767·2 feet with an estimated probable error of $\pm$ 0·5 metre or $\pm$ 1·6 feet. In latitude 39° and azimuth 103°, log. [radius of curvature] or log $\rho = 6{\cdot}805\ 19$ and the reduction to sea level †

$$-\frac{lh}{\rho} + \frac{lh^2}{\rho^2} \quad \text{becomes} - 3{\cdot}646\ 7 \text{ metres} \pm 0{\cdot}000\ 9 \text{ metre}$$

hence with the measured length of the base $l = 11\ 292{\cdot}823\ 1$ metres the final or reduced base $L = 11\ 289{\cdot}176\ 4$ metres and its logarithm 4·052 662 26.

The probable error of measure of the base is:

	mm.
For the part between East Base and D, where the number of measures is three	$\pm$ 1·57
For the part lying between D and Upsilon from double measures	$\pm$ 4·57
And for the remaining part to West Base	$\pm$ 1·24
Total for length of base	$\pm$ 4·99

The probable error due to uncertainty in the length of the rods is $1882 \times 6\mu = \pm\ 11{\cdot}29$ millimetres.

The probable error produced by an uncertainty of one-half, metre in the value of the elevation of the base above the ocean $\pm$ 0·90 millimetres.

Combining these probable errors we get for the base $\sqrt{(4{\cdot}99)^2 + (11{\cdot}29)^2 + (0{\cdot}90)^2} = \pm\ 12{\cdot}38$ millimeters, which is about $\frac{1}{912\ 000}$ part of the length and corresponds to the logarithmic difference $\varepsilon M l = \pm\ 4{\cdot}8$ in units of the seventh place of decimals.

This may be taken to represent the error of measure and of reduction to sea level, combining it with the probable error due to our practical unit of length, the Committee Metre, taken as $\pm \frac{3}{4}\mu$, we get $\sqrt{(12{\cdot}4)^2 + (8{\cdot}5)^2} = \pm\ 15{\cdot}0$ millimetres, or about $\frac{1}{752\ 000}$ part of the length.

	m.
Resulting length of the El Paso Base	11 289·176 4
	$\pm$15 0
and its logarithm	4·052 662 26
	$\pm$ 58

* Top above ground 1·06 metres.

† To this reduction as well as to its probable error attaches the uncertainty due to any error in the radius of curvature of the reference spheroid. Strictly speaking, to the height should be added the elevation of the equipotential surface (to which spirit levels necessarily conform) under El Paso as produced inland from the sea level.

ABSTRACTS OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, FORMING THE EL PASO BASE NET, 1879–80, 1895.

El Paso East Base, El Paso County, Colorado. September 29 to October 13, 1879. 30-centimetre theodolite, No. 108. O. H. Tittmann, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base net adjustment.	Final seconds in triangulation.
		°	′	″		″	″	″	″
	Azimuth mark	0	00	00·00					
1	Holcolm Hills	67	48	34·45		+0·10	34·55	−0·652	33·898
2	Big Springs	141	17	47·36		−0·12	47·24	+0·864	48·104
3	Corral Bluffs	229	57	10·48		+0·13	10·61	−0·216	10·394
4	El Paso West Base	282	48	01·59		−0·06	01·53	−0·051	01·479
5	Divide	340	58	34·49		−0·09	34·40	+0·055	34·455

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·17.

El Paso West Base, El Paso County, Colorado. October 17 to November 1, 1879. 30-centimetre theodolite, No. 108. O. H. Tittmann, observer.

No. of direction.	Objects observed.	°	′	″	Approximate probable error.	Reduction to sea level. ″	Resulting seconds. ″	Corrections from base net adjustment. ″	Final seconds in triangulation. ″
6	Divide	0	00	00·00		+0·14	00·14	−0·463	59·677
7	Holcolm Hills	50	45	56·46		+0·03	56·49	+0·716	57·206
8	El Paso East Base	69	55	02·84		−0·06	02·78	−0·466	02·314
9	Corral Bluffs	148	54	53·34		+0·01	53·35	+0·214	53·564
	Bear Creek	202	33	37·97					
	Glen Eyrie	219	44	24·05					

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·12.

Corral Bluffs, El Paso County, Colorado. November 2 to November 6, 1879. 30-centimetre theodolite, No. 108. O. H. Tittmann, observer.

No. of direction.	Objects observed.	°	′	″	Approximate probable error.	Reduction to sea level. ″	Resulting seconds. ″	Corrections from base net adjustment. ″	Final seconds in triangulation. ″
10	El Paso West Base	0	00	00·00		+0·01	00·01	+0·042	00·052
11	Divide	15	36	52·44		+0·09	52·53	−0·162	52·368
12	El Paso East Base	48	09	17·97		+0·13	18·10	−0·042	18·058
13	Holcolm Hills	56	40	11·06		+0·13	11·19	+0·097	11·287
14	Big Springs	112	06	29·68		−0·09	29·59	+0·065	29·655
	Bear Creek	255	15	13·89					
	Glen Eyrie	275	18	41·66					

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·12

ABSTRACTS OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, FORMING THE EL PASO BASE NET, 1879–80, 1895—continued.

Holcolm Hills, El Paso County, Colorado. July 20 to August 16, 1880. 30-centimetre theodolite, No. 108. O. H. Tittmann, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base net adjustment.	Final seconds in triangulation.
		°	′	″		″	″	″	″
	Holt	0	00	00·00		+0·03	00·03		
	Square Bluffs	29	14	12·37		−0·08	12·29		
20	Big Springs	86	36	27·88		−0·05	27·83	−0·370	27·460
21	Corral Bluffs	156	28	04·74		+0·12	04·86	+0·457	05·317
22	El Paso East Base	165	48	35·85		+0·09	35·94	−0·190	35·750
23	El Paso West Base	181	38	58·15		+0·03	58·18	+0·265	58·445
24	Divide	212	10	36·84		−0·11	36·73	−0·162	36·568

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) = ± 0″·81.

Divide, El Paso County, Colorado. November 12 to November 19, 1879. 30-centimetre theodolite, No. 108. O. H. Tittmann, observer. August 1 to August 11, 1895. 30-centimetre theodolite, No. 118. F. D. Granger and J. B. Boutelle, observers.

No. of direction.	Objects observed.	°	′	″	Approximate probable error ″	Reduction to sea level ″	Resulting seconds ″	Corrections ″	Final seconds ″
15	Holcolm Hills	0	00	00·000		−0·11	59·89	+0·191	00·081
16	Big Springs	33	19	29·190	±0·134*	−0·114	29·076	−0·926	28·150
17	El Paso East Base	46	47	59·87		−0·08	59·79	+0·492	60·282
18	Corral Bluffs	83	14	11·24		+0·08	11·32	−0·314	11·006
19	El Paso West Base	98	42	24·31		+0·13	24·44	+0·557	24·997
	Pikes Peak	126	59	19·980	0·111*	+0·240	20·220		
	Bison Peak	168	29	32·642	0·088*	−0·104	32·538		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·19 in 1879 and ± 0″·68 in 1895.

Big Springs, El Paso County, Colorado. August 21 to September 3, 1880. 30-centimetre theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers. June 23 to July 6, 1895. 30-centimetre, theodolite, No. 118. F. D. Granger and J. B. Boutelle, observers.

No. of direction.	Objects observed.	°	′	″	Approximate probable error ″	Reduction to sea level ″	Resulting seconds ″	Corrections ″	Final seconds ″
25	Corral Bluffs	0	00	00·000		−0·10	59·90	+0·002	59·902
26	El Paso East Base	27	23	27·51		−0·13	27·38	−0·268	27·112
27	Divide	33	35	42·180	±0·115†	−0·137	42·043	−0·370	41·673
28	Holcolm Hills	54	42	04·99		−0·05	04·94	+0·636	05·576
	Square Bluffs	138	58	19·83		+0·06	19·89		
	Cramers Gulch	188	03	38·61		−0·10	38·51		
	Dry Camp	235	37	57·119	0·228†	−0·040	57·079		
	Plateau	279	28	24·329	0·100†	+0·108	24·437		
	Pikes Peak	344	22	41·563	0·121†	−0·083	41·480		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·42 in 1880 and ± 0″·77 in 1895.

* Directions marked with a * depend on the probable error ± 0″·134 of Big Springs during the second occupation.
† Directions marked with a † depend on the probable error ± 0″·115 of Divide during the second occupation.

FIGURE ADJUSTMENT.

*Observation equations.**

1 $0=-0{\cdot}168+(19)-(17)+(5)-(4)+(8)-(6)$

2 $0=-0{\cdot}760+(12)-(10)+(9)-(8)+(4)-(3)$

3 $0=+0{\cdot}415+(12)-(11)+(18)-(17)+(5)-(3)$

4 $0=+1{\cdot}327+(23)-(22)+(1)-(4)+(8)-(7)$

5 $0=+0{\cdot}377+(24)-(22)+(1)-(5)+(17)-(15)$

6 $0=+0{\cdot}073+(22)-(21)+(13)-(12)+(3)-(1)$

7 $0=+1{\cdot}243+)26)-(25)+(14)-(12)+(3)-(2)$

8 $0=-2{\cdot}125+(27)-(26)+(2)-(5)+(17)-(16)$

9 $0=-2{\cdot}599+(28)-(26)+(2)-(1)+(22)-(20)$

10 $0=+3{\cdot}24-0{\cdot}77(6)+1{\cdot}18(8)-0{\cdot}41(9)-1{\cdot}89(10)+3{\cdot}30(11)-1{\cdot}41(12)-1{\cdot}20(17)+2{\cdot}85(18)$
$-1{\cdot}65(19)$

11 $0=+21{\cdot}22-6{\cdot}06(7)+6{\cdot}47(8)-0{\cdot}41(9)-1{\cdot}89(10)+15{\cdot}94(12)-14{\cdot}06(13)-12{\cdot}80(21)+20{\cdot}22(22)$
$-7{\cdot}42(23)$

12 $0=-10{\cdot}97-0{\cdot}77(6)+6{\cdot}06(7)-5{\cdot}29(8)-1{\cdot}98(15)+3{\cdot}63(17)-1{\cdot}65(19)-5{\cdot}41(22)+7{\cdot}42(23)$
$-2{\cdot}01(24)$

13 $0=-15{\cdot}94-3{\cdot}30(11)+4{\cdot}33(12)-1{\cdot}03(14)-8{\cdot}79(16)+11{\cdot}64(17)-2{\cdot}85(18)-4{\cdot}06(25)+23{\cdot}43(26)$
$-19{\cdot}37(27)$

14 $0=+1{\cdot}59-3{\cdot}30(11)+4{\cdot}33(12)-1{\cdot}03(14)-1{\cdot}98(15)+4{\cdot}83(17)-2{\cdot}85(18)-0{\cdot}40(20)+2{\cdot}41(22)$
$-2{\cdot}01(24)-4{\cdot}06(25)+8{\cdot}14(26)-4{\cdot}08(28)$

Correlate equations.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
(1)				+1	+1	−1			−1					
(2)							−1	+1	+1					
(3)		−1	−1			+1	+1							
(4)	−1	+1		−1										
(5)	+1	...	+1	...	−1	...	...	−1	...	......	....	......	....	....
(6)	−1									−0·77		−0·77		
(7)				−1							− 6·06	+6·06		
(8)	+1	−1		+1						+1·18	+ 6·47	−5·29		
(9)		+1								−0·41	− 0·41			
(10)	...	−1	...	...	...	...	...	...	...	−1·89	− 1·89	......	....	....
(11)			−1							+3·30			− 3·30	−3·30
(12)		+1	+1			−1	−1			−1·41	+15·95		+ 4·33	+4·33
(13)						+1					−14·06			
(14)							+1						− 1·03	−1·03
(15)	...	...	...	...	−1	...	...	...	...	......	....	−1·98	....	−1·98
(16)								−1					− 8·79	
(17)	−1		−1		+1			+1		−1·20		+3·63	+11·64	+4·33
(18)			+1							+2·85			− 2·85	−2·85
(19)	+1									−1·65		−1·65		
(20)	...	...	...	...	...	...	...	...	−1	......	....	......	....	−0·40

* Number of conditions in the net 14, of which 9 relate to the sums of angles and 5 to the ratio of sides.
The side equations are established with 8 places of logarithms and differences of 1″ are cut off at the sixth place.

FIGURE ADJUSTMENT—continued.

Correlate equations—Completed.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
(21)						−1					−12·80			
(22)				−1	−1	+1			+1		+20·22	−5·41		+2·41
(23)				+1							− 7·42	+7·42		
(24)					+1							−2·01		−2·01
(25)	...	...	...	...	...	...	−1	...	...	.....	....	......	− 4·06	−4·06
(26)							+1	−1	−1				+23·43	+8·14
(27)								+1					−19·37	
(28)									+1					−4·08

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
0=− 0·168	+6	−2	+2	+2	−2			+2		+ 1·50	+ 6·47	− 9·80	−11·64	− 4·83
− 0·760		+6	+2	−2		−2	−2			− 1·11	+10·96	+ 5·29	+ 4·33	+ 4·33
+ 0·415			+6		−2	−2	−2	−2		− 0·66	+15·95	− 3·63	− 6·86	− 0·05
+ 1·327				+6	+2	−2			−2	+ 1·18	−15·11	+ 1·48		− 2·41
+ 0·377	.	.	.	.	+6	−2		+2	−2	− 1·20	−20·22	+ 9·01	+11·64	+ 2·39
+ 0·073						+6	+2		−2	+ 1·41	+ 3·01	− 5·41	− 4·33	− 1·92
+ 1·243							+6	−2	−2	+ 1·41	−15·95		+22·13	+ 6·84
− 2·125								+6	+2	− 1·20		+ 3·63	−22·37	− 3·31
− 2·599									+6		+20·22	− 5·41	−23·43	− 9·41
+ 3·24	.	.	.	.	.	.	.	.	.	+30·89	−11·12	− 7·27	−39·08	−30·90
+21·22											+1 162·16	−235·40	+69·06	+117·79
−10·97												+173·48	+42·25	+ 12·45
−15·94													+1 192·22	+302·24
+ 1·59														+175·47

Resulting values of correlates and of corrections to angular directions.

			″	″
C_1=+0·493 2	C_8=+0·521 4	and	(1)=−0·651 9	(15)=+0·190 7
C_2=+0·168 0	C_9=+0·393 8		(2)=+0·863 8	(16)=−0·926 1
C_3=−0·093 3	C_{10}=−0·090 67		(3)=−0·216 4	(17)=+0·492 5
C_4=−0·274 7	C_{11}=−0·020 63		(4)=−0·050 5	(18)=−0·313 9
C_5=−0·176 5	C_{12}=+0·052 14		(5)=+0·055 0	(19)=+0·556 8
C_6=−0·193 1	C_{13}=+0·046 04		(6)=−0·463 4	(20)=−0·370 1
C_7=−0·051 4	C_{14}=−0·059 32		(7)=+0·715 7	(21)=+0·457 2
			(8)=−0·465 8	(22)=−0·190 3
			(9)=+0·213 6	(23)=+0·265 3
Σ of + corr's. =4·643 4			(10)=+0·042 4	(24)=−0·162 1
Σ of − corr's. =4·653 2			(11)=−0·162 1	(25)=+0·002 5
			(12)=−0·042 3	(26)=−0·267 9
and $[pvv]=4·893\ 7$			(13)=+0·097 0	(27)=−0·370 4
$-[wC]=4·893\ 6$			(14)=−0·065 1	(28)=+0·635 8

Mean error of an observed *direction* $m_1=\sqrt{\frac{[pvv]}{n}}=\pm 0''·59$ **where** n = **number of conditional equations; mean error of an angle** $m=m_1\sqrt{2}=\pm 0''·84$, **also probable error of the same** $=\pm 0''·56$.

TRIANGLES OF THE EL PASO BASE NET, COLORADO, 1879–1895.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log. *s*.	Distance in metres.
		°	′	″	″	″	″		
1	Divide	51	54	24·65	+0·064	24·714	0·109	4·052 662 26	11 289·176
	El Paso East Base	58	10	32·87	+0·106	32·976	0·109	4·085 933 07	12 188·02
	El Paso West Base	69	55	02·64	−0·002	02·638	0·110	4·129 440 11	13 472·25
				00·16			0·328		
2	Corral Bluffs	48	09	18·09	−0·085	18·005	0·113	4·052 662 26	11 289·176
	El Paso West Base	78	59	50·57	+0·679	51·249	0·114	4·172 476 96	14 875·68
	El Paso East Base	52	50	50·92	+0·166	51·086	0·113	4·082 009 11	12 078·39
				59·58			0·340		
3	Corrall Bluffs	15	36	52·52	−0·205	52·315	0·064	4·085 933 07	12 188·02
	El Paso West Base	148	54	53·21	+0·677	53·887	0·065	4·368 826 86	23 379·05
	Divide	15	28	13·12	+0·871	13·991	0·064	4·082 009 11	12 078·39
				58·85			0·193		
4	Corral Bluffs	32	32	25·57	+0·120	25·690	0·158	4·129 440 11	13 472·25
	Divide	36	26	11·53	−0·806	10·724	0·158	4·172 476 97	14 875·68
	El Paso East Base	111	01	23·79	+0·271	24·061	0·159	4·368 826 86	23 379·05
				00·89			0·475		
5	Holcolm Hills	9	20	31·08	−0·647	30·433	0·052	4·172 476 97	14 875·68
	Corral Bluffs	8	30	53·09	+0·139	53·229	0·052	4·132 546 81	13 568·97
	El Paso East Base	162	08	36·06	+0·435	36·495	0·053	4·448 717 64	28 100·73
				00·23			0·157		
6	Holcolm Hills	25	10	53·32	−0·193	53·127	0·240	4·082 009 11	12 078·39
	Corral Bluffs	56	40	11·18	+0·055	11·235	0·240	4·375 080 34	23 718·12
	El Paso West Base	98	08	56·86	−0·502	56·358	0·240	4·448 717 64	28 100·73
				01·36			0·720		
7	Holcolm Hills	55	42	31·87	−0·619	31·251	0·365	4·368 826 86	23 379·05
	Corral Bluffs	41	03	18·66	+0·259	18·919	0·365	4·269 174 15	18 585·50
	Divide	83	14	11·43	−0·505	10·925	0·365	4·448 717 63	28 100·73
				01·96			1·095		
8	Holcolm Hills	15	50	22·24	+0·456	22·696	0·074	4·052 662 26	11 289·18
	El Paso East Base	145	00	33·02	−0·601	32·419	0·075	4·375 080 34	23 718·12
	El Paso West Base	19	09	06·29	−1·182	05·108	0·074	4·132 546 81	13 568·97
				01·55			0·223		
9	Holcolm Hills	46	22	00·79	+0·028	00·818	0·154	4·129 440 11	13 472·25
	El Paso East Base	86	49	60·15	−0·707	59·443	0·155	4·269 174 15	18 585·50
	Divide	46	47	59·90	+0·302	60·202	0·154	4·132 546 81	13 568·97
				00·84			0·463		

TRIANGLES OF THE EL PASO BASE NET, COLORADO, 1879–1895—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log. *s*.	Distance in metres.
		°	′	″	°	′	″		
10	Holcolm Hills	30	31	38·55	−0·427	38·123	0·189	4·085 933 07	12 188·02
	El Paso West Base	50	45	56·35	+1·179	57·529	0·189	4·269 174 16	18 585·50
	Divide	98	42	24·55	+0·366	24·916	0·190	4·375 080 35	23 718·12
				59·45			0·568		
11	Big Springs	27	23	27·48	−0·270	27·210	0·366	4·172 476 97	14 875·68
	Corral Bluffs	63	57	11·49	+0·107	11·597	0·366	4·463 151 95	29 050·39
	El Paso East Base	88	39	23·37	−1·080	22·290	0·365	4·509 545 78	32 325·54
				02·34			1·097		
12	Big Springs	33	35	42·14	−0·373	41·767	0·635	4·368 826 86	23 379·05
	Corral Bluffs	96	29	37·06	+0·227	37·287	0·636	4·623 059 02	41 981·60
	Divide	49	54	42·24	+0·612	42·852	0·635	4·509 545 79	32 325·54
				01·44			1·906		
13	Big Springs	54	42	05·04	+0·633	05·673	0·633	4·448 717 64	28 100·73
	Corral Bluffs	55	26	18·40	−0·032	18·368	0·633	4·452 618 46	28 354·27
	Holcolm Hills	69	51	37·03	+0·828	37·858	0·633	4·509 545 80	32 325·54
				00·47			1·899		
14	Big Springs	6	12	14·66	−0·103	14·557	0·112	4·129 440 11	13 472·25
	El Paso East Base	160	19	12·84	+0·809	13·649	0·111	4·623 059 03	41 981·60
	Divide	13	28	30·71	+1·419	32·129	0·112	4·463 151 98	29 050·39
				58·21			0·335		
15	Big Springs	27	18	37·56	+0·904	38·464	0·320	4·132 546 81	13 568·97
	El Paso East Base	73	29	12·69	+1·515	14·205	0·320	4·452 618 46	28 354·27
	Holcolm Hills	79	12	08·11	−0·180	08·290	0·319	4·463 151 98	29 050·39
				58·36			0·959		
16	Big Springs	21	06	22·90	+1·006	23·906	0·363	4·269 174 15	18 585·50
	Divide	33	19	29·19	−1·116	28·074	0·363	4·452 618 47	28 354·27
	Holcolm Hills	125	34	08·90	+0·208	09·108	0·362	4·623 059 04	41 981·61
				00·99			1·088		

PROBABLE ERRORS.

Determination of the probable error of the length of the side Big Springs to divide, connecting the central with the western section of the main triangulation.

This side is related to the base by the expression—

$$\frac{\text{Big Springs to Divide}}{\text{El Paso Base}}=\frac{\sin(9-8)\sin(5-3)\sin(14-11)}{\sin(12-10)\sin(18-17)\sin(27-25)}$$

Take $F=\log\sin(9-8)+\log\sin(5-3)+\log\sin(14-11)-\log\sin(12-10)$ $-\log\sin(18-17)-\log\sin(27-25)$.

Establishing and solving the transfer equations, we find the reciprocal of the weight or $\frac{1}{P}=7{\cdot}545$; also the mean error m_F and the probable error r_F both expressed in units of the sixth place of decimals in their logarithms, viz, $\pm 1{\cdot}62$ and $\pm 1{\cdot}10$ respectively. Hence log. distance Big Springs to Divide $\underset{\pm 1\ 10}{4{\cdot}623\ 059\ 03}$, and the length of the side in metres $\underset{\pm 106}{41\ 981{\cdot}60}$. The probable error equals about $\frac{1}{396\ 000}$ part of the length.

To this must be added the uncertainty arising from the base measure, viz, $\frac{41\ 982}{11\ 289}\times 0{\cdot}015$. Hence we have—

Probable error of length of side Big Springs to Divide $\sqrt{({\cdot}106)^2+({\cdot}056)^2}$ $=\pm 0{\cdot}120$ metre.

The probable error of the side Holcolm Hills to Big Springs may without sensible error be taken as $\pm\frac{1}{396\ 000}$ of the length and $\pm\frac{28\ 354}{11\ 289}\times 0{\cdot}015$. Hence—

Probable error of length of side Holcolm Hills to Big Springs $\sqrt{({\cdot}070)^2+({\cdot}038)^2}$ $=\pm 0{\cdot}080$ metre.

GENERAL DESCRIPTION OF STATIONS FORMING THE EL PASO BASE NET, COLORADO.

El Paso East Base, El Paso County; established in 1878 by O. H. Tittmann. This station is situated on Munson & Hamlin's ranch, commonly known as the Townsend ranch, which is included in the southwest quarter of section 33 and the southeast quarter of section 32, township 12 south, range 63 west of the principal meridian. The west gable of Munson & Hamlin's barn bears north 14° 35′·3 east, and is 376·6 metres distant from the geodetic point. The underground mark is a line on a copper tack in a lead plug in drill hole in the top of a granite post, 1 foot square and about 2½ feet long, set in cement, the top of the post being 3½ feet below the surface and having the letters U.S.E.B. cut on it. Over this about 6 inches of earth was packed, then a 6-inch bed of concrete, on which a similar granite post, marked in the same way, was set as a surface mark. Around this a brick pier, rising about 2½ feet above the surface was built and capped with a so-called lava stone about 26 inches square and 6 inches thick, having upon it the letters U.S.E.B. Arches at right angles to each other run through the pier a few inches above the ground, in order that the mark on the surface stone can be seen.

El Paso West Base, El Paso County; established in 1878 by O. H. Tittmann. This station is about 15 miles northeast of Colorado Springs and about 1 mile north of the sheep corral and main spring of water of the Pugsley ranch, so called. The monument stands on a knoll somewhat higher than a similar one to the southward and lower than a knoll to the northward of it. The geodetic point is marked in a manner exactly similar to that of East Base, except that the letters W.B. are substituted for the letters E.B.

Divide, El Paso County; established in 1879 by O. H. Tittmann. This station is situated on the western end of the middle and largest of three small hills or buttes rising more than 150 feet from the plateau, near the head of Bracket Creek, about 5 miles southwest of Bijou Basin post-office, about 3 miles east of the town of Eastonville on the U.P.D.& G.R.R., and about one-fourth mile south of the bluffs forming the southern edge of a large plateau or mesa. The underground mark is a flat stone about 18 inches square, 10 inches thick, irregular in shape, and sunk about 18 inches below the surface. A cross cut on lead run into a hole 1½ inches in diameter marks the geodetic point. Four reference stones were set in the ground north, east, south, and west approximately. Lines drawn from the leaden bolts in these stones intersect at the geodetic point. The marks in the lead in the north and east stones are each distant 5 feet 11⅞ inches, and those in the south and west stones 6 feet one-eighth inch from the center. The surface mark now (1895) consists of the capstone of the former stone pier, 20 inches square and 6 inches thick, having a hole 1 inch in diameter and 3 inches deep in its center, buried flush with the surface.

Corral Bluffs, El Paso County; established in 1879 by O. H. Tittmann. This station is situated on the edge of the bluffs forming the northern boundary of what is known as the "Big Corral," a natural formation used to pen up cattle during the "round-ups." It is on the highest land in that immediate vicinity, and commands a view of the plains as far south as the Arkansas River. Some of the houses in Manitou are visible from here as well as the rocks forming the entrance to the "Garden of the Gods."

A solid brick pier, capped with a hewn stone, was built over the underground mark at this station. The top of the capstone is 1·276 metres above the surface of the ground.

Holcolm Hills, El Paso County; established in 1879 by O. H. Tittmann. This station is on the highest land bordering the valley of Bracket Creek on the east. The knoll on which it is located overlooks the plains toward the west and the head of the valley of the Big Sandy toward the northeast. To the eastward the land drains into Horse Creek. The station is about 1 mile northeast of the Paint Rocks.

The underground mark is a cross cut on lead run into a hole drilled in the upper surface of an irregular stone, about 12 by 18 by 18 inches, set 3 feet below the surface. The letters U.S. △T.S. are roughly cut on the stone.

The surface mark is a hole filled with lead on the upper surface of a large irregular stone about 2½ by 3 by 1¼ feet in size, also having the letters U.S.T.S. cut on it. Four smaller stones with crosses cut on them were set approximately north, south, east, and west and 4 feet distant from the center of the station.

A cairn was built over the station.

Big Springs, El Paso County; established in 1879 by O. H. Tittmann. This station

is situated about 30 miles east of Colorado Springs and about 6 miles south of Mr. Pebble's home ranch, known as Big Springs. It is on the highest point within a radius of about 6 miles. A road connecting various outlying ranches with the home ranch runs close to the station.

The underground mark is an irregular white conglomerate stone, having a triangle and the letters U.S. △T.S. roughly cut on it, set about one-half metre below the surface. The surface mark is a small leaden bolt in an irregular red sandstone. Four reference marks of similar sandstone, each having a small hole filled with lead in its upper surface, were set in the ground at a distance of 1 metre from the center. A pile of loose stones was erected over the station.

(*e*) *Yolo Base Line, California, 1881.*

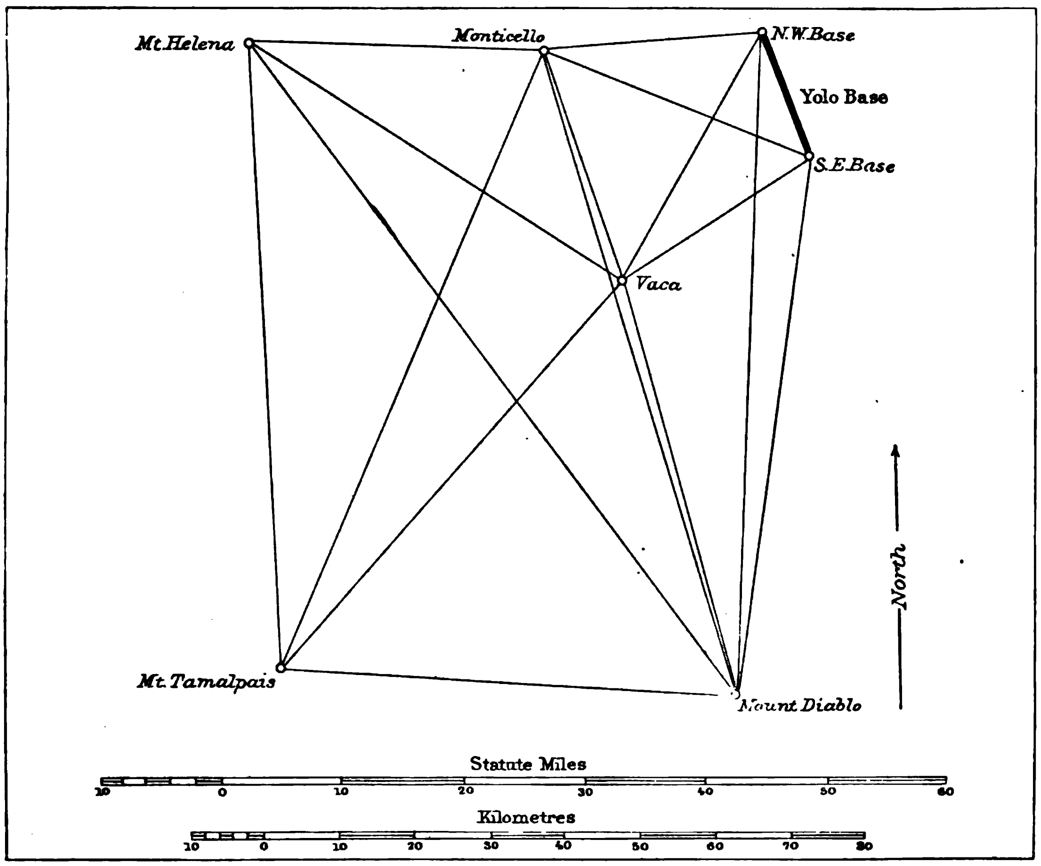
LOCATION, MEASUREMENT, AND LENGTH.

Location of the base line.—The line is in Yolo County, in the Sacramento Valley, nearly midway between the Sacramento River and the Vaca Mountains and a short distance to the westward of the towns of Davisville and Woodland. The site was selected by Assistant G. Davidson in April, 1876; it is about 28 kilometres (17½ statute miles) to the westward of Sacramento City. Approximately the latitude of the southern terminus is 38° 31′ 34″ and that of the northern terminus is 38° 40′·6 the azimuth of the line at Southeast Base is 163° 07′·2, making the inclination of the base with the meridian at its middle point about 16° 53′·8. The length of the line is approximately 17·5 kilometres, or a little short of 11 statute miles. The ground at Southeast Base is 21·6 metres and at Northwest Base 46·6 metres above the mean tidal level of the Pacific; these two ends of the base were finally located and marked in June, 1880. The southeast station is about 25 metres from the left bank of Putah Creek. Appendix No. 8, Report of the United States Coast and Geodetic Survey for 1882, entitled "Report of the measurement of the Yolo Base, Yolo County, California," by G. Davidson, Assistant, contains all needful information respecting the organization of the party and its method of working, as well as the description of monuments and markings of the base. As the high ridge of Willow Slough lies directly across the line, it was decided to build a brick shaft of about 10 metres elevation above the ground at Southeast Base and one of 5 metres elevation at Northwest Base for occupation with the theodolite in connection with the triangulation and the astronomical observations. The underground marks of the base underneath the monuments are copper bolts inserted in stone blocks. A line of levels was run twice over the base and a stub placed at every 50 metres. The soil is a rich, dark loam, sandy near Southeast Base and composed of stiff clay near Northwest Base; the grade is very easy, almost level, except when nearing the upper end, where for about 100 metres the ascending slope is nearly 4°. A line of spirit levels connects the base with the half-tide level at San Francisco Bay.

The measurement of the base.—The line was measured twice and in opposite directions, and some parts of it thrice; the time spent in the first measure was 20 days, in the second 18, and in the third 8 working days. The measurement was in charge of Assistant G. Davidson; it commenced September 19 and was completed November 24, 1881. The apparatus used was of new construction, the measuring

bars being composed of two metals, steel and zinc, rigidly joined and cut to lengths, so as to nearly compensate for changes of temperature. The bars are 5 metres in length and contact is made by means of contact-slide pieces. A full description of it is given in Appendix No. 7, report of 1882, entitled "Construction and description of a new compensation primary base apparatus, including the determination of the length of the corresponding 5-metre standard bar," by Charles A. Schott, Assistant, pp. 107–138. A third report, Appendix No. 11, Coast and Geodetic Survey Report

No. 8.



for 1883, pp. 273–288, contains the results of the base measures. These publications render any lengthy report of the base in this place superfluous.

The length of the compound 5-metre base bars 1 and 2.—For the purpose of determining the length of these measuring bars, two 5-metre standard bars of steel* were procured and standardized by means of the combined length of 5 single metre steel bars known as A, B, C, D, E. The first operation, therefore, consisted in determining the length of these several metres in terms of the Committee Metre. To effect this, the following subsidiary measures and results had to be obtained—

* For particulars see Coast and Geodetic Survey Report for 1882, pp. 117–136.

(a) The length of the Saxton stop-metre comparator from 4 measures made between April, 1872, and March, 1879, by various observers,

$$S_m = 1m \text{ at } 20^\circ{\cdot}20\ C.$$

(b) The length of the brass decimetre, known as D_{1878}, from measures made between May, 1878, and October, 1880, by several observers,

$$D_{1878} = 0{\cdot}1m + \overset{\mu}{1{\cdot}799}\ (t - 14^\circ{\cdot}67\ C.).$$

(c) The length of the brass centimetre, known as C_{1878}, from observations made in October, 1878,

$$C_{1878} = 0{\cdot}01m + \overset{\mu}{0{\cdot}180}\ (t - 30^\circ{\cdot}5\ C.).$$

(d) Values of 1 turn of the Bessel-Repsold comparators Nos. 1 and 2, depending on preceding lengths,

$$\text{No. } 1 = \underset{\pm\,{\cdot}01}{276{\cdot}06} + 0{\cdot}0036\ (t - 14^\circ\ C.) \text{ microns.}$$

$$\text{No. } 2 = \underset{\pm\,{\cdot}01}{276{\cdot}33} + 0{\cdot}0036\ (t - 14^\circ\ C.) \text{ microns.}$$

The inequalities of the screws of these comparators were determined and a table of corrections was constructed for whole and fractional turns.

(e) Values of 1 turn of the Fauth & Co. comparators, known as Nos. 3 and 4, from comparisons made in May and June, 1881, one turn of No. 3 and of No. 4 = $254{\cdot}53 + 0{\cdot}002\ (t - 20^\circ\ C.)$ microns. The inequalities for these screws were likewise determined.

(f) The subsidiary steel metres A, B, C, D, E are end metres, with platinum iridium cylinders of 2 millimetres diameter projecting 0·5 millimetre beyond their end surfaces. For comparison of length and determination of the coefficient of expansion they were placed side by side with the Committee Metre in the middle position, in a trough filled with glycerin the temperature of which could be changed and was read by means of two immersed standard thermometers. Observations made between December, 1880, and February, 1881, gave the following results:

$$A = 1m + \underset{\pm\,{\cdot}52}{175{\cdot}81\mu} + \underset{\pm\,17}{6{\cdot}359\mu}\ (t - 57{\cdot}53\ F.).$$

$$B = 1m + \underset{\pm\,{\cdot}48}{157{\cdot}14\mu} + \underset{\pm\,8}{6{\cdot}388\mu}\ (t - 57{\cdot}53\ F.).$$

$$C = 1m + \underset{\pm\,{\cdot}45}{174{\cdot}77\mu} + \underset{\pm\,12}{6{\cdot}396\mu}\ (t - 57{\cdot}53\ F.).$$

$$D = 1m + \underset{\pm\,{\cdot}51}{155{\cdot}31\mu} + \underset{\pm\,7}{6{\cdot}363\mu}\ (t - 57{\cdot}53\ F.).$$

$$E = 1m + \underset{\pm\,{\cdot}51}{164{\cdot}77\mu} + \underset{\pm\,19}{6{\cdot}345\mu}\ (t - 57{\cdot}53\ F.).$$

Also Σ or $A + B + C + D + E$

$$= 5m + \underset{\pm\,1{\cdot}92}{\overset{\mu}{827{\cdot}80}} + \underset{\pm\,60}{\overset{\mu}{31{\cdot}851}}\ (t - 57{\cdot}53\ F.).$$

$$= 5m + \underset{\pm\,1{\cdot}92}{\overset{\mu}{827{\cdot}80}} + \underset{\pm\,108}{\overset{\mu}{57{\cdot}332}}\ (t - 14^\circ{\cdot}18\ C.).$$

Length and coefficient of expansion of the 5-metre standard bars Nos. I and II—known as the 5-metre office and field standards. They are of steel and terminate in steel cylinders similar to those of the metres. Firmly attached to them at their ends are two zinc bars, each of half the length of the steel bar, one on each side, with two Borda scales at the middle of each standard bar. They were mounted on rollers in a water-

tight wooden box and immersed in glycerin which could be raised to different temperatures; four thermometers gave the temperature of the fluid.

Mounted on the same movable platform in the office comparing room was a second box containing the five metres, joined together by spiral springs to make proper contact * and carefully aligned. Six thermometers gave the temperature of this compound bar, which at the contact ends only was exposed to the air. The cylindric ends of the bars protrude through small holes in thin brass plates and are secured by india-rubber diaphragms, permitting contact with the screw comparators mounted on independent brick piers. Observations made in March, 1881, comprising 35 sets, gave the coefficients of expansion of the office or No. I standard $\underset{\pm 32}{0{\cdot}000\,011\,491}$ and of the field or No. II standard $\underset{\pm 41}{0{\cdot}000\,011\,495}$ for the centigrade scale.

The comparisons for length made at various times gave the following results:

1881, April and May	II—I=$65{\cdot}7\mu+1{\cdot}2\mu$	at $20^{\circ}{\cdot}46$C
1882, May and June	I =$5m+1\ 221{\cdot}4\mu\pm1{\cdot}8\mu$	19·15
1883, January and February	II—I=$61{\cdot}0\mu\pm0{\cdot}8\mu$	12·68
1883, February	I =$5m+1\ 047{\cdot}8\mu\pm0{\cdot}6\mu$	16·11
1883, February	II =$5m+1\ 155{\cdot}9\mu\pm0{\cdot}5\mu$	16·96

$$\text{Whence length of } \mathrm{I} = 5m + 1\ \underset{\pm\,2{\cdot}1}{101{\cdot}8\mu} + \underset{\pm{\cdot}16}{57{\cdot}46^{\mu}}\ (t - 17^{\circ}{\cdot}07\ \mathrm{C.}).$$

$$\text{and of } \mathrm{II} = 5m + 1\ \underset{\pm\,2{\cdot}1}{163{\cdot}0\mu} + \underset{\pm{\cdot}21}{57{\cdot}47}\ (t - 17{\cdot}07\ \mathrm{C.}).$$

The length of the base measuring 5-metre bars depend on the latter value. Comparisons with this field standard were made every morning before commencing the measure on the base; generally between the hours of 7 and 8 a. m. The mean error from two sets of comparisons is for base bar 1, $\pm 3{\cdot}8\mu$ and for base bar 2, $\pm 5{\cdot}2\mu$. On other days bihourly comparisons were made extending over day and night hours in order to ascertain the diurnal variation in length of the roughly compensated base bars. In connection with this work the temperature of the bars is given by the readings of mercurial thermometers.

The following table gives the length of the base bars [$5m$ + tabular quantity (in microns)] between the hours 8 a. m. and 6 p. m. and for two periods, from bihourly comparisons on 5 days in September and from hourly comparisons on 4 days in October and November, 1881.

Bar.	8^h a. m.	9	10	11	Noon.	1 p. m.	2	3	4	5	6^h
1	30		29		27		26		24		27
1	56	69	71	86	84	86	88	80	79	69	68
2	121		114		117		111		106		110
2	333	336	350	359	363	359	365	362	355	345	335

* During the progress of the comparisons the metres were variously arranged as to relative position.

The Borda Scales were found unreliable on account of the zinc bars taking up a new set after changes of temperature. The length of the base bars adopted in the computation was determined as follows: For any one day it depends on the morning comparison with the standard, to which is added differentially the diurnal difference for the particular hour, taken from the normal or tabular values and multiplied by a factor of the ratio of the range of temperature on the particular day to the normal range. Before and during the first measure of the base the diurnal range of length was very small, but during the second and partial third measure it had sensibly increased. This change was most pronounced between October 4 and October 15. Fractional lengths of the base bars were measured by means of a 3-metre steel rod and fractional parts of a metre by means of a brass-metre scale, and for transfers to the ground a small ivory scale graduated to half millimetres was employed; one or the other of these means came into use at the base end, at the 17-kilometre marks and the subdivisions at the crossing of fences and at the numerous temporary stopping places during the measures. For reduction to sea level, we have from spirit leveling the bench mark at Woodland 17·78 metres above the half-tide level of San Francisco Bay and the average height of the base, including 1·25 metres for height of bars, 26·8 metres. The reduction is separately applied to each kilometre. The total amount equals 68·06 millimetres.

Tabular results of measures of the Yolo Base.

Kilometre divisions.	First measure.	Second measure.	Third measure.	Mean.	Δ_1	Δ_2	Δ_3
	m.	*m.*	*m.*	*m.*	*mm.*	*mm.*	*mm.*
1	999·938 57	999·936 74	999·942 30	999·939 20	+0·63	+2·46	−3·10
2	·865 46	·862 57	·864 42	·864 15	−1·31	+1·58	−0·27
3	·919 67	·920 53		·920 10	+0·43	−0·43	
4	·955 17	·953 37		·954 27	−0·90	+0·90	
5	·935 61	·934 55		·935 58	−1·03	+1·03	
6	·993 26	·992 40		·992 83	−0·43	+0·43	
7	·910 55	·911 54		·911 04	+0·49	−0·50	
8	·948 47	·950 99		·949 73	+1·26	−1·26	
9	·961 21	·965 86		·963 54	+2·33	−2·32	
10	·973 48	·975 17		·974 32	+0·84	−0·85	
11	·911 85	·909 45		·910 65	−1·20	+1·20	
12	·914 50	·917 03		·915 76	+1·26	−1·27	
13	·932 28	·931 14	999·932 43	·931 95	−0·33	+0·81	−0·48
14	·957 92	·954 12	·958 57	·956 87	−1·05	+2·75	−1·70
15	·903 46	·899 77	·902 53	·901 92	−1·54	+2·15	−0·61
16	·875 82	·872 70	·873 59	·874 04	−1·78	+1·34	+0·45
17	999·936 22	999·933 33	999·934 54	999·934 70	−1·52	+1·37	+0·16
(18)	487·683 51	487·679 34	487·681 00	487·681 28	−2·23	+1·94	+0·28
Σ	17 486·518 01	17 486·500 60	— —	17 486·511 93			

The kilometres count from the southeast end from which the first measure started, the second one was run in the opposite direction, and the third measure was equally divided as to direction.

The probable error of the resulting length.—That due to the measure proper, which includes errors of contact, of transfer (bar to ground and back to bar), of fractional parts of bars, of inclination, of alignment, and of assigned length of bars, is $\pm 3{\cdot}29$ millimetres; also the *mean* error of a single measure of 1 kilometre $= \pm 1{\cdot}81$ millimetres. The probable error arising from the field comparisons of the standard bar with the base bars has been taken as $\pm 1{\cdot}2$ millimetres, and that due to uncertainty in the length of the bars due to diurnal variation has been estimated as ± 5 millimetres. The probable error due to uncertainty in the length of the measuring bar is given by $\pm 2{\cdot}1\,\mu \times 3\,497 = \pm 7{\cdot}34$ millimetres; the probable error due to uncertainty in the expansion coefficient is but $\pm 0{\cdot}3$ millimetre, and the probable error depending on an uncertainty of 0·35 metre in the height of the base is $\pm 1{\cdot}0$ millimetre; hence the probable error of the whole base, combining the 6 separate values, equals $\pm 9{\cdot}6$ millimetres, which is about $\frac{1}{1\,821\,000}$ part of the length, or $\pm 0{\cdot}009\,6$ metre and in the sixth place of log's $\pm 0{\cdot}238$.

This may be taken to represent the measuring error. Combining it with the probable error due to that of our practical unit of length, the Committee Metre, taken as $\pm \frac{3}{4}\mu$, we get

$\sqrt{(9{\cdot}6)^2 + (13{\cdot}1)^2} = \pm 16{\cdot}3$ millimetres, or about $\frac{1}{1\,073\,000}$ part of the length.

Resulting length of the Yolo Base, 17 486·511 9 and its logarithm 4·242 703 189.
± 16 3 ± 405

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE YOLO BASE NET. 1876, 1880, 1882, 1884, 1891–92.

Yolo Southeast Base, Yolo County, California. July 22 to August 16, 1880. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″	″	″
4	Yolo Northwest Base	0 00 00·000	± ·043	− ·002	59·998	+ ·232	00·230
	Marysville Butte	15 32 39·320	·085	− ·002	39·318		
	Pine Hill	89 51 47·540	·069	+ ·024	47·564		
1	Mount Diablo	204 49 35·777	·085	+ ·021	35·798	+ ·021	35·819
2	Vaca	252 41 55·204	·079	+ ·045	55·249	− ·220	55·029
3	Monticello	310 54 36·564	·074	− ·046	36·518	− ·064	36·454

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''{\cdot}52$.

Yolo Northwest Base, Yolo County, California. August 19 to September 10, 1880. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″	″	″
5	Yolo Southeast Base	0 00 00·000	± ·038	− ·001	59·999	− ·160	59·839
6	Mount Diablo	20 04 24·623	·080	+ ·008	24·631	− ·082	24·549
7	Vaca	47 20 34·153	·067	+ ·042	34·195	+ ·060	34·255
8	Monticello	103 42 21·384	·059	+ ·007	21·391	+ ·188	21·579
	Marysville Butte	200 07 47·730	·075	+ ·006	47·736		
	Pine Hill	283 13 29·522	·069	+ ·005	29·527		

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''{\cdot}46$.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE YOLO BASE NET. 1876, 1880, 1882, 1884, 1891–92—continued.

Vaca, Solano and Napa counties, California. October 30 to December 11, 1880. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
10	Yolo Southeast Base	0	00	00·000	±·064	+·001	00·001	+0·111	00·112
	Pine Hill	12	12	58·103	·080	+·030	58·133		
11	Mount Diablo	109	03	23·738	·083	−·040	23·698	−·347	23·351
12	Mount Tamalpais	166	20	42·497	·107	+·052	42·549	−·078	42·471
13	Mount Helena	248	47	11·185	·103	−·082	11·103	+·488	11·591
14	Monticello	288	18	44·230	·108	−·032	44·198	+·141	44·339
	Marysville Butte	318	15	04·533	·098	+·020	04·553		
9	Yolo Northwest Base	334	38	38·711	·073	+·003	38·714	−·259	38·455

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·67.

Monticello, Yolo County, California. September 23 to October 19, 1880. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
20	Mount Helena	0	00	00·000	±·052	−·003	59·997	+·121	00·118
	Marysville Butte	116	50	54·208	·073	+·036	54·244		
	Pine Hill	175	09	43·409	·053	+·006	43·415		
15	Yolo Northwest Base	175	30	36·288	·051	·000	36·288	−·080	36·208
16	Yolo Southeast Base	202	42	51·850	·084	−·001	51·849	+·091	51·940
17	Vaca	252	48	57·254	·066	−·026	57·228	−·077	57·151
18	Mount Diablo	253	17	07·113	·107	−·041	07·072	−·137	06·935
19	Mount Tamalpais	292	27	41·105	·062	+·039	41·144	+·062	41·206

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·51.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE YOLO BASE NET. 1876, 1880, 1882, 1884, 1891–92—continued.

Mount Diablo, Contra Costa County, California. June 25 to September 8, 1876. 50-centimetre theodolite, No. 5. G. Davidson, C. Rockwell, and W. Eimbeck, observers. November 14 to December 29, 1884. 50-centimetre theodolite, No. 115. R. A. Marr, observer. (G. Davidson, chief of party.) June 28 to July 19, 1892. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
22	Mount Helena	0	00	00·000	± ·066	— ·082	59·918	— ·645	59·273
23	Monticello	20	03	30·643	·090	— ·032	30·611	— ·102	30·509
24	Vaca	20	19	59·505	·098	— ·024	59·481	+ ·319	59·800
	Azimuth Mark (Clayton)	25	49	17·204	{·092 / * ·074}	— ·010	17·194		
25	Yolo Northwest Base	38	39	09·129	* ·115	·000	09·129	+ ·086	09·215
	Marysville Butte	38	40	30·881	·094	+ ·005	30·886		
26	Yolo Southeast Base	43	24	20·921	* ·106	·000	20·921	+ ·524	21·445
	Mount Lola	73	06	31·834	·089	+ ·185	32·019		
	Pine Hill	76	14	00·524	·106	+ ·043	00·567		
	Round Top	97	32	04·551	·107	+ ·181	04·732		
	Mount Conness	122	21	10·679	† ·062	+ ·029	10·708		
	Mocho	180	16	12·207	{* ·111 / † ·062}	— ·080	12·127		
	Loma Prieta	211	22	06·404	* ·084	— ·011	06·393		
	Sierra Morena	249	16	39·858	* ·092	+ ·046	39·904		
21	Mount Tamalpais	310	12	09·226	·095	— ·008	09·218	— ·047	09·171
	Ross Mountain	339	08	13·637	* ·087	— ·042	13·595		
							Mean	+ ·023	

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·72.

Mount Helena, Napa County, California. September 23 to November 26, 1876. 50-centimetre theodolite, No. 5. G. Davidson, W. Eimbeck, observers. August 14 to August 21, 1891. 50-centimetre theodolite, No. 115. E. F. Dickins, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
29	Mount Diablo	0	00	00·000	± ·058	— ·073	59·927	+ ·183	00·110
30	Mount Tamalpais	33	43	57·142	·071	— ·004	57·138	+ ·303	57·441
	Ross Mountain	102	52	47·356		+ ·032	47·388		
	Cold Spring	153	08	42·324		— ·045	42·279		
	Mount Sanhedrin	193	02	53·251		— ·089	53·162		
	Snow Mountain West	208	09	11·511		— ·038	11·473		
	Snow Mountain East	208	37	44·912	·059				
	Azimuth Mark (Woods)	225	16	49·643	·052	+ ·007	49·650		(49·618)
	Marysville Butte	265	31	14·523	·078	+ ·042	14·565		
	Mount Lola	281	54	43·341	·083	+ ·140	43·481		
	Pine Hill	303	14	10·280	·083	+ ·004	10·284		
	Round Top	305	18	41·177	·074	+ ·005	41·182		
27	Monticello	306	46	16·071	·076	— ·002	16·069	+ ·008	16·077
28	Vaca	340	03	44·142	·113	— ·045	44·097	— ·621	43·476
							Mean	— ·032	

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·62.

* The directions marked by a * depend on the probable error ± 0″·074 of the azimuth mark during the second occupation.

† The directions marked by a † depend on the probable error ± 0″·062 of Mocho during the third occupation.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE YOLO BASE NET. 1876, 1880, 1882, 1884, 1891–92—completed.

Mount Tamalpais, Marin County, California. August 24 to October 9, 1882. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
34	Mount Diablo	0	00	00·000	±·053	−·011	59·989	+·277	00·266
	Mocho	23	47	56·302	·064	−·071	56·231		
	Sierra Morena	61	37	29·923	·076	−·037	29·886		
	Ross Mountain	230	31	28·940	·090	−·043	28·897		
31	Mount Helena	263	31	35·075	·086	−·006	35·069	+·054	35·123
32	Monticello	289	01	42·852	·072	+·045	42·897	+·048	42·945
33	Vaca	307	25	02·177	·062	+·048	02·225	−·380	01·845

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·54.

FIGURE ADJUSTMENT.

*Observation equations.**

No.	
1	$0 = -0.814 + (4) - (3) + (16) - (15) + (8) - (5)$
2	$0 = +0.043 + (3) - (2) + (10) - (14) + (17) - (16)$
3	$0 = -1.041 + (4) - (2) + (10) - (9) + (7) - (5)$
4	$0 = -0.726 + (6) - (5) + (4) - (1) + (26) - (25)$
5	$0 = +0.178 + (7) - (6) + (11) - (9) + (25) - (24)$
6	$0 = -0.313 + (3) - (1) + (18) - (16) + (26) - (23)$
7	$0 = +0.071 + (19) - (17) + (14) - (12) + (33) - (32)$
8	$0 = -0.349 + (20) - (19) + (32) - (31) + (30) - (27)$
9	$0 = +0.779 + (20) - (17) + (14) - (13) + (28) - (27)$
10	$0 = -2.603 + (24) - (22) + (29) - (28) + (13) - (11)$
11	$0 = -0.254 + (22) - (21) + (34) - (31) + (30) - (29)$
12	$0 = +1.046 - 1.960\,6(2) - 1.304\,8(3) - 0.655\,8(4) + 1.940\,0(5) - 3.340\,8(7) + 1.400\,8(8) + 0.474\,3(15) - 1.760\,4(16) + 1.286\,1(17)$
13	$0 = -2.809 + 1.904\,4(1) - 1.248\,6(2) - 0.655\,8(4) + 1.940\,0(5) - 4.084\,7(6) + 2.144\,7(7) + 1.416\,7(24) - 6.359\,3(25) - 4.942\,6(26)$
14	$0 = +198.013 + 1.904\,4(1) - 3.209\,2(2) + 1.304\,8(3) + 1.760\,4(16) - 258.757\,4(17) + 256.997\,0(18) + 439.179\,2(23) - 444.121\,8(24) - 4.942\,6(26)$
15	$0 = -5.817 + 1.904\,4(1) - 3.209\,2(2) + 1.304\,8(3) + 1.760\,4(16) - 4.301\,5(17) + 2.541\,1(19) + 0.760\,9(21) - 5.703\,5(24) - 4.942\,6(26) + 6.333\,6(32) - 7.944\,4(33) + 1.610\,8(34)$
16	$0 = -3.964 + 0.760\,9(21) - 5.681\,8(22) + 4.920\,9(24) + 4.256\,2(28) - 5.804\,6(29) + 1.548\,4(30) + 2.188\,6(31) - 3.799\,4(33) + 1.610\,8(34)$
17	$0 = -1.205 + 3.192\,2(17) - 2.541\,1(19) - 0.651\,1(20) + 3.206\,5(27) - 4.754\,9(28) + 1.548\,4(30) + 2.188\,6(31) - 6.333\,6(32) + 4.145\,0(33)$

* Number of conditions in the net 17, of which 11 refer to angle and 6 to side equations; the latter are established with 9 places in the logarithms, and the logarithmic differences for 1″ are given in units of the sixth place.

FIGURE ADJUSTMENT—continued.

Correlate equations.

Corrections.	$u = \frac{100}{p}$	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
(1)	3·58				−1		−1					
(2)	3·48		−1	−1								
(3)	3·41	−1	+1				+1					
(4)	3·04	+1		+1	+1							
(5)	3·00	−1	..	−1	−1	...	..	...	..	...	...	...
(6)	3·50				+1	−1						
(7)	3·31			+1		+1						
(8)	3·21	+1										
(9)	3·39			−1		−1						
(10)	3·27	..	+1	+1	...	...	...	...	...	...	...	...
(11)	3·55					+1					−1	
(12)	4·00							−1				
(13)	3·92									−1	+1	
(14)	4·03		−1					+1		+1		
(15)	3·12	−1	...	...	...	...	...	...	...	...	...	...
(16)	3·57	+1	−1				−1					
(17)	3·30		+1					−1		−1		
(18)	4·00						+1					
(19)	3·24							+1	−1			
(20)	3·13	...	...	...	...	...	...	...	+1	+1	...	...
(21)	3·76											−1
(22)	3·30										−1	+1
(23)	3·67						−1					
(24)	3·82					−1					+1	
(25)	4·18	...	...	...	−1	+1	..	..	...	...	...	...
(26)	3·98				+1		+1					
(27)	3·44								−1	−1		
(28)	4·14									+1	−1	
(29)	3·20										+1	−1
(30)	3·36	...	...	...	..	...	...	...	+1	...	...	+1
(31)	3·60								−1			−1
(32)	3·38							−1	+1			
(33)	3·24							+1				
(34)	3·14											+1

Correlate equations—Continued.

Corrections.	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
(1)		+1·904 4	+1·904 4	+1·904 4		
(2)	+1·960 6	−1·248 6	−3·209 2	−3·209 2		
(3)	−1·304 8		+1·304 8	+1·304 8		
(4)	−0·655 8	−0·655 8				
(5)	+1·940 0	+1·940 0	....	....	....	....
(6)		−4·084 7				
(7)	−3·340 8	+2·144 7				
(8)	+1·400 8					
(9)						
(10)	....	....	....	....	....	....
(11)						
(12)						
(13)						
(14)						
(15)	+0·474 3	....	....	....	....	....
(16)	−1·760 4		+1·760 4	+1·760 4		

FIGURE ADJUSTMENT—completed.

Correlate equations—Completed.

Corrections.	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
(17)	+1·286 1		−258·757 4	−4·301 5		+3·192 2
(18)			+256·997 0			
(19)				+2·541 1		− 2·541 1
(20)	....	....	....	....	....	−0·651 1
(21)				+0·760 9	+0·760 9	
(22)					−5·681 8	
(23)			+439·179 2			
(24)		+1·416 7	−444·121 8	−5·703 5	+4·920 9	
(25)	....	−6·359 3	......	....	....	....
(26)		+4·942 6	+4·942 6	+4·942 6		
(27)						+3·206 5
(28)					+4·256 2	−4·754 9
(29)					−5·804 6	
(30)	....	....	....	....	+1·548 4	+1·548 4
(31)					+2·188 6	+2·188 6
(32)				+6·333 6		−6·333 6
(33)				−7·944 4	−3·799 4	+4·145 0
(34)				+1·610 8	+1·610 8	

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
0 = − 0·814	+19·35	− 6·98	+ 6·04	+ 6·04		− 6·98					
+ 0·043		+21·06	+ 6·75			+ 6·98	− 7·33		− 7·33		
− 1·041			+19·49	+ 6·04	+ 6·70						
− 0·726				+21·28	− 7·68	+ 7·56					
+ 0·178	....	....	....	....	+21·75	......	....	....	....	− 737	
− 0·313						+22·21					
+ 0·071							+21·19	− 6·62	+ 7·33		
− 0·349								+20·15	+ 6·57		+ 6·96
+ 0·779									+21·96	− 8·06	
− 2·603	....	....	....	....	....	....	....	....	....	+21·93	− 6·50
+ 0·254											+20·36

Normal equations—Completed.

	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
− 0·814	− 6·632 1	− 7·813 6	+ 1·835 3	+ 1·835 3		
+ 0·023	− 0·743 5	+ 4·345 1	− 844·566 7	− 4·862 2		+10·534 3
− 1·041	−25·694 6	+ 3·630 5	+ 11·168 0	+11·168 0		
− 0·726	− 7·813 6	+ 17·325 6	+ 12·853 8	+12·853 8		
+ 0·178	−11·058 0	− 10·598 3	+1 696·545 3	+21·787 4	−18·797 8	....
− 0·313	+ 1·835 3	+ 12·853 8	− 572·781 1	+11·018 5		
+ 0·071	− 4·244 1		− 853·899 4	−24·719 3	−12·310 1	+16·069 9
− 0·340				+13·174 4	− 2·676 3	−28·919 0
+ 0·779	− 4·244 1		+ 853·899 4	+14·195 0	+17·620 7	−43·287 8
− 2·603	....	+ 5·411 8	−1 696·545 3	−21·787 4	+ 1·352 4	+19·685 3
+ 0·254				+ 2·196 9	− 0·654 6	− 2·676 3
0 = + 1·046	+92·245 9	− 19·637 0	−1 136·965 0	−57·021 1		+13·548 1
− 2·809		+378·566 7	−2 279·339 0	+93·290 5	+26·630 9	
+198·013			+1 946 641·906 4	+13 512·216 0	−8 348·529 6	−2 725·817 7
− 5·817	....	....	....	+719·565 7	+ 0·906 7	−308·513 1
− 3·964					+464·246 3	−109·510 1
− 1·205						+401·399 2

Resulting values of correlates and of corrections to angular directions.

$C_1 = +0·033\ 900$	$C_6 = -0·011\ 325$	$C_{10} = +0·163\ 816$	$C_{14} = -0·000\ 088\ 967$
$C_2\ \ +\ ·023\ 593$	$C_7\ \ +\ ·019\ 388$	$C_{11}\ \ +\ ·036\ 790$	$C_{15}\ \ +\ ·019\ 867\ 4$
$C_3\ \ +\ ·010\ 217$	$C_8\ \ +\ ·009\ 930$	$C_{12}\ \ +\ ·017\ 565\ 2$	$C_{16}\ \ +\ ·012\ 020\ 3$
$C_4\ \ +\ ·043\ 760$	$C_9 = +0·039\ 218$	$C_{13} = +0·000\ 276\ 1$	$C_{17} = +0·016\ 115\ 3$
$C_5 = +0·066\ 122$			

″	″	″	″
(1) = +0·020 6	(10) = +0·110 6	(19) = +0·061 5	(27) = +0·008 3
(2) − ·219 9	(11) − ·346 8	(20) + ·121 0	(28) − ·621 3
(3) − ·063 9	(12) − ·077 6	(21) − ·047 1	(29) + ·183 2
(4) + ·231 6	(13) + ·488 4	(22) − ·644 6	(30) + ·303 4
(5) − ·159 8	(14) + ·141 1	(23) − ·101 8	(31) + ·053 5
(6) − ·082 2	(15) − ·079 8	(24) + ·318 7	(32) + ·048 4
(7) + ·060 4	(16) + ·091 1	(25) + ·086 1	(33) − ·380 1
(8) + ·187 8	(17) − ·077 3	(26) = +0·523 6	(34) = +0·276 8
(9) = −0·258 8	(18) = −0·136 8		

Σ of the + corrections 3″·316

Σ of the − corrections 3·298

Also $[pvv] = 0·6245$

$-[wC] = 0·6249$

Mean error of a *direction* of unit weight $m_1 = \sqrt{\frac{[pvv]}{n}} = \pm 0''·192$, where n = number of conditional equations; the average weight of a direction is 0·285; hence $m = m_1 / \sqrt{p_0} = \pm 0''·36$ and the mean error of an observed angle $= m\sqrt{2} = \pm 0''·51$; also the probable error of the same $= \pm 0''·34$. (Cf. Appendix No. 9—Annual Report of the Survey for 1885.)

TRIANGLES OF THE YOLO BASE NET, CALIFORNIA, 1876–1892.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angle. ″	Spherical excess. ″	Log *s*.	Distances in metres.
1	Vaca	25	21	21·287	+0·369	21·656	0·424	4·242 703 19	17 486·512
	Yolo N. W. Base	47	20	34·196	+0·220	34·416	0·424	4·477 552 13	30 029·78
	Yolo S. E. Base	107	18	04·749	+0·452	05·201	0·425	4·590 907 73	38 985·91
				00·232			1·273		
2	Monticello	27	12	15·561	+0·171	15·732	0·416	4·242 703 19	17 486·512
	Yolo N. W. Base	103	42	21·392	+0·348	21·740	0·415	4·570 085 01	37 160·80
	Yolo S. E. Base	49	05	23·480	+0·295	23·775	0·416	4·461 001 97	28 906·93
				00·433			1·247		
3	Vaca	71	41	15·803	−0·031	15·772	0·802	4·570 085 01	37 160·80
	Monticello	50	06	05·379	−0·168	05·211	0·803	4·477 552 12	30 029·78
	Yolo S. E. Base	58	12	41·269	+0·156	41·425	0·803	4·522 072 61	33 271·52
				02·451			2·408		

TRIANGLES OF THE YOLO BASE NET, CALIFORNIA, 1876–1892—continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angle.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
4	Monticello	77	18	20·940	+0·003	20·943	0·794	4·590 907 73	38 985·91
	Yolo N. W. Base	56	21	47·196	+0·127	47·323	0·794	4·522 072 61	33 271·52
	Vaca	46	19	54·516	−0·400	54·116	0·794	4·461 001 97	28 906·93
				02·652			2·382		
5	Mount Diablo	4	45	11·792	+0·437	12·229	0·450	4·242 703 19	17 486·512
	Yolo N. W. Base	20	04	24·632	+0·078	24·710	0·450	4·859 908 79	72 428·38
	Yolo S. E. Base	155	10	24·200	+0·211	24·411	0·450	4·947 451 15	88 603·56
				00·624			1·350		
6	Mount Diablo	18	19	09·648	−0·233	09·415	1·339	4·590 907 73	38 985·91
	Vaca	134	24	44·984	−0·088	44·896	1·340	4·947 451 15	88 603·56
	Yolo N. W. Base	27	16	09·564	+0·143	09·707	1·339	4·754 580 63	56 830·39
				04·196			4·018		
7	Mount Diablo	23	04	21·440	+0·205	21·645	1·365	4·477 552 12	30 029·78
	Vaca	109	03	23·697	−0·457	23·240	1·365	4·859 908 79	72 428·38
	Yolo S. E. Base	47	52	19·451	−0·241	19·210	1·365	4·754 580 63	56 830·39
				04·588			4·095		
8	Mount Diablo	18	35	38·518	+0·188	38·706	2·154	4·461 001 97	28 906·93
	Monticello	77	46	30·784	−0·057	30·727	2·154	4·917 451 14	88 603·56
	Yolo N. W. Base	83	37	56·760	+0·270	57·030	2·155	4·954 725 45	90 100·14
				06·062			6·463		
9	Mount Diablo	23	20	50·310	+0·625	50·935	2·189	4·570 085 01	37 160·80
	Monticello	50	34	15·223	−0·228	14·995	2·189	4·859 908 78	72 428·38
	Yolo S. E. Base	106	04	60·720	−0·084	60·636	2·188	4·954 725 45	90 100·14
				06·253			6·566		
10	Mount Diablo	0	16	28·870	+0·420 0	29·290 0	0·021 0	4·522 072 61	33 271·52
	Monticello	0	28	09·844	−0·060 7	09·783 3	0·021 0	4·754 580 63	56 830·39
	Vaca	179	15	20·500	+0·488 7	20·988 7	0·020 0	4·954 725 45	90 100·14
				59·214			0·062 0		
11	Mount Helena	33	17	28·028	−0·630	27·398	1·038	4·522 072 61	33 271·52
	Monticello	107	11	02·769	+0·198	02·967	1·037	4·762 757 83	57 910·57
	Vaca	39	31	33·095	−0·347	32·748	1·038	4·586 334 73	38 577·56
				03·892			3·113		
12	Mount Diablo	20	19	59·563	+0·963	60·526	1·800	4·762 757 83	57 910·57
	Mount Helena	19	56	15·830	+0·805	16·635	1·800	4·754 580 63	56 830·39
	Vaca	139	43	47·405	+0·835	48·240	1·801	5·032 332 46	107 728·96
				02·798			5·401		

TRIANGLES OF THE YOLO BASE NET, CALIFORNIA, 1876–1892—continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angle.	Spherical excess.	Log s.	Distances in metres.
		°	′	″	″	″	″		
13	Mount Diablo	20	03	30·693	+0·543	31·236	2·817	4·586 334 73	38 577·56
	Mount Helena	53	13	43·858	+0·175	44·033	2·817	4·954 725 45	90 100·14
	Monticello	106	42	52·925	+0·258	53·183	2·818	5·032 332 46	107 728·96
				07·476			8·452		
14	Mount Tamalpais	18	23	19·328	−0·429	18·899	1·607	4·522 072 61	33 271·52
	Monticello	39	38	43·916	+0·139	44·055	1·607	4·827 980 08	67 294·58
	Vaca	121	58	01·649	+0·219	01·868	1·608	4·951 716 47	89 478·04
				04·893			4·822		
15	Mount Tamalpais	25	30	07·828	−0·005	07·823	2·699	4·586 334 73	38 577·56
	Mount Helena	86	57	41·069	+0·295	41·364	2·700	4·951 716 47	89 478·04
	Monticello	67	32	18·853	+0·059	18·912	2·700	4·918 061 79	82 806·00
				07·750			8·099		
16	Mount Tamalpais	43	53	27·156	−0·434	26·722	3·269	4·762 757 83	57 910·57
	Mount Helena	53	40	13·041	+0·925	13·966	3·269	4·827 980 08	67 294·58
	Vaca	82	26	28·554	+0·566	29·120	3·270	4·918 061 80	82 806·00
				08·751			9·808		
17	Mount Diablo	49	47	50·700	−0·597	50·103	4·192	4·918 061 79	82 806·00
	Mount Tamalpais	96	28	24·920	+0·223	25·143	4·193	5·032 332 46	107 728·96
	Mount Helena	33	43	57·211	+0·120	57·331	4·192	4·779 637 67	60 205·71
				12·831			12·577		
18	Mount Diablo	69	51	21·393	−0·054	21·339	4·310	4·951 716 47	89 478·04
	Mount Tamalpais	70	58	17·092	+0·229	17·321	4·310	4·954 725 44	90 100·14
	Monticello	39	10	34·072	+0·198	34·270	4·310	4·779 637 67	60 205·71
				12·557			12·930		
19	Mount Diablo	70	07	50·263	+0·366	50·629	2·724	4·827 980 08	67 294·58
	Mount Tamalpais	52	34	57·764	+0·657	58·421	2·723	4·754 580 63	56 830·39
	Vaca	57	17	18·851	+0·269	19·120	2·723	4·779 637 68	60 205·71
				06·878			8·170		

PROBABLE ERRORS.

Determination of the probable errors of the length of the sides common to the net and the adjacent chains of triangulation.

For the side Mount Helena to Mount Diablo we make use of the expression—*

$$\frac{\text{Mount Helena to Mount Diablo}}{\text{Yolo Base}}=\frac{\sin(2-1)\sin(7-5)\sin(13-11)}{\sin(10-9)\sin(26-24)\sin(29-28)}$$

hence the function

$$F=\log\sin(2-1)+\log\sin(7-5)+\log\sin(13-11)-\log\sin(10-9)-\log\sin(26-24)-\log\sin(29-28)$$

Establishing and solving the transfer equations, we find for the reciprocal of the weight $\frac{1}{p}=74{\cdot}469$; also the mean error m_F and the probable error r_F, both expressed in units of the sixth place of decimals in the logarithm, viz: $\pm 1{\cdot}654$ and $\pm 1{\cdot}116$, respectively; hence log. distance Mount Helena to Mount Diablo $\underset{\pm\ 1\ 116}{5{\cdot}032\ 332\ 46}$ and the distance $\underset{\pm\ 0{\cdot}277}{107\ 728{\cdot}96}$ metres. The probable error corresponds to about $\frac{1}{389\ 000}$ part of the length. To this must be added the proportional error depending upon that of the base measure, viz: $0{\cdot}016\ 3\times\frac{107\ 729}{17\ 486}=\pm 0{\cdot}100$ metre; hence probable error of length of side Mount Helena to Mount Diablo $\sqrt{(0{\cdot}277)^2+(0{\cdot}100)^2}=\pm 0{\cdot}295$ metre.

For the side Mount Tamalpais to Mount Diablo we use the expression—

$$\frac{\text{Mount Tamalpais to Mount Diablo}}{\text{Yolo Base}}=\frac{\sin(7-5)\sin(2-1)\sin(12-11)}{\sin(10-9)\sin(26-24)\sin(34-33)}$$

hence the function

$$F=\log\sin(7-5)+\log\sin(2-1)+\log\sin(12-11)-\log\sin(10-9)-\log\sin(26-24)-\log\sin(34-33)$$

Establishing and solving the transfer equations, we get $\frac{1}{p}=89{\cdot}796$; also $m_F=\pm 1{\cdot}817$ and $r_F=\pm 1{\cdot}225$; hence log. distance Mount Tamalpais to Mount Diablo $\underset{\pm\ 1\ 22}{4{\cdot}779\ 637\ 68}$ and distance $\underset{\pm\ 0{\cdot}17}{60\ 205{\cdot}71}$ metres. The probable error is about $\frac{1}{370\ 000}$ part of the length. Combining with this the proportional error arising from the base measure, or $0{\cdot}016\ 3\times\frac{60\ 206}{17\ 486}=\pm 0{\cdot}056$ metre, we have probable error of length of side Mount Tamalpais to Mount Diablo $\sqrt{(0{\cdot}17)^2+(0{\cdot}056)^2}=\pm 0{\cdot}18$ metre.

GENERAL DESCRIPTION OF STATIONS FORMING THE YOLO BASE NET, CALIFORNIA.

Yolo Southeast Base, Yolo County; established in 1876 by G. Davidson. This station is situated in the northwest quarter of section 19, township 8 north, range 2 east, Diablo meridian, 3⅛ miles west and 1⅛ miles south of Davisville and about 25 metres from the left bank of Putah Creek. The geodetic point is marked as follows: The sub-

*Appendix No. 9, Report for 1885.

surface mark is a fine needle hole in a German-silver plug inserted in a copper bolt in the top of a granite block 35 inches long by 20 inches square at the base and dressed to 12 inches square at the top and having the letters U.S.C.G.S. deeply cut on it. The top of the block is 4½ feet below the surface and a glass hemisphere is placed over the copper bolt. The surface mark is a fine needle hole in a copper bolt set in lead on the top of a granite block, 25 inches square by 26 inches deep, having the letters U.S.C.S.S.E. YOLO BASE cut on it. The top of this block is even with the surface of the ground and the block itself is in the center of a solid brickwork pier, having a base of 70 inches square at a depth of 50 inches below the surface, battering to 54 inches square at the surface. This brickwork was carried up as a hollow pier to a height 33¼ feet above the ground and capped with a granite slab, 40 inches square by 8 inches thick with a 1¼ inch hole in the center. Charcoal and charcoal dust were mixed with the earth in filling in around the subsurface part of the structure.

Four reference marks were set, consisting of granite blocks 1 foot square and 1¼ feet high, with copper bolts and drill holes on the top. They were incased in brickwork with their tops 18 inches below the surface. Two were set in line to Northwest Base at distances of 18 feet 11$\frac{1}{16}$ inches and 327 feet 10 inches from the center and two in line at right angles thereto eastwardly at distances of 20 feet five-eighths inch and 328 feet 5$\frac{5}{16}$ inches from the center.

Yolo Northwest Base, Yolo County; established in 1876 by G. Davidson. This station is situated in the extreme southeast corner of the southeast quarter of section 28, township 10 north, range 1 east, Diablo meridian, 4⅓ miles west of the railroad passing through woodland, and immediately on the north side of the county road running west toward Madison and Copay Valley.

The marking at this station was practically identical with that at Southeast Base, with the exception that the hollow brick pier was carried to a height of only about 12 feet above the surface, and the letters N.W. were substituted for S.E. on the granite blocks. No reference marks were established.

Vaca, Solano County; established in 1876 by W. Eimbeck. This station is situated in the southern part of section 9, township 6 north, range 2 west of the Diablo meridian, on the dividing ridge between Solano and Napa counties, about 7 miles a little north of west from Vacaville. The mountain slopes gently to the eastward, but is much more precipitous on the western slope. The station can, however, be approached from either side. Mr. A. J. Raney, living in 1880 at Gordon Valley, to the westward of the mountain, is referred to as knowing the locality well. The underground mark is a soda-water bottle filled with sand, buried neck upward; the top is 1·18 feet below the surface, and has a copper nail stuck in the sand. Over this was built a rough stone pier laid in Portland cement. The center mark at the surface is a copper bolt, five-eighths inch in diameter by 5 inches long, projecting about one-fourth inch and having a silver pin set in it, set in cement in a large stone in the center of the pier.

The top of the pier is 3·44 feet above the underground mark. The astronomical piers built of concrete, situated as follows, serve as reference marks. Vertical circle pier bears south 6° 02′ east (true), distant 15·9 metres, and zenith telescope pier south 58° 42′ east (true), distant 72·1 feet from the geodetic point.

Monticello, Yolo County; established in 1876 by W. Eimbeck. This station is situated in the extreme northeast corner of section 4, township 9 north, range 3 west of

the Diablo meridian, on the highest summit of the mountain range lying between the Sacramento and Berryessa valleys, about 5 miles northward from the town of Monticello in the lower portion of Berryessa Valley. It may be most readily approached from this town, from which it is visible. Its location is well known to the people of the neighborhood. The lower underground mark is a loaded metallic cartridge placed ball downward in a half inch hole, 1½ inches deep, drilled in the bottom of a 6-inch round hole 1 foot deep excavated in the sandstone rock, the top of the cartridge being 2·5 feet below the surface. Over this was placed a stone about 4 inches square and 1 foot long, with a copper bolt in the top, its top being 1·1 feet below the surface. A rough stone foundation was laid over this and crowned with a large stone coming even with the surface. As a surface mark a copper bolt five-eighths by 5 inches, with a silver pin in it, was set in cement in a hole drilled in this stone. The bolt projects about one-fourth inch above the stone. A rough stone theodolite pier was then built to a height of 3·84 feet and capped with a flat stone 32 inches square, having crosslines on it. Reference marks are the transit pier 31·288 feet north and 3·687 feet east of the station; the latitude pier 31·413 feet north and 8·823 feet east of the station, and the vertical circle pier bearing south 38° 17′ east (true) and distant 19·786 metres from the station.

Mount Diablo, Contra Costa County; established in 1852 by R. D. Cutts. Mount Diablo is a prominent and well-known peak of the coast range of mountains about 26½ miles to the eastward of San Francisco. The station is on the highest summit, about 3 feet from the starting point for the public lands survey of California, and can be readily approached by a graded wagon road reaching the summit (1876).

The geodetic point is marked by a cross cut on a copper bolt firmly cemented in a hole drilled into the solid rock of the mountain. Over this a brick pier was built 3 feet 3 inches above the surface (1892), and a three-fourth inch copper bolt cemented in a hole in the top, with a cross cut on it, marks the point.

The reference marks are the latitude and transit piers built of brick, distant nearly due west 167·84 feet and 171·42 feet, respectively, from the geodetic point.

Mount Helena, Napa County; established in 1876 by W. Eimbeck. This station is situated on the summit of Mount Helena, which is about 12 miles distant in a northerly direction by wagon road and trail from Calistoga, a station on the Southern Pacific Railroad 73 miles from San Francisco. It is 7 feet 1¾ inches distant in a southeast direction from a basaltic rock, with a large drill hole in it, marking one angle of the boundary between Lake and Napa counties. The mountain top toward the south and east is smooth, but falls off precipitously and is very rough toward the north and west.

The geodetic point is marked by a fine drill hole and cross cut on the top of a copper bolt, one-half inch in diameter by 5 inches long, set in cement in a drill hole and projecting about one-fourth of an inch above the bed rock. Over this was erected a brick pier for the theodolite to rest on, having a half-inch drill hole on the top to mark the station. The reference marks are 4 brick piers situated as follows: Transit pier in a south southeast direction, distant 55 feet 11 inches; latitude pier a little more to the eastward, distant 58 feet 2½ inches; vertical circle pier about southeast, distant 109 feet 3½ inches, and the collimator pier a little west of north, distant 7 feet 7½ inches from the geodetic point.

Mount Tamalpais, Marin County; established in 1852 by R. D. Cutts. This station is situated on the highest part of the peninsula north of San Francisco Bay, about 10 miles

distant from the Golden Gate, on the western and highest of three peaks on the bold ridge running east and west. The top of this peak is tolerably flat and the station is on the highest part, at an elevation of about 2 570 feet above the sea.

The geodetic point was re-marked in 1881 as follows: The underground mark is a stone bottle set in concrete, neck up, 20 inches below the surface, around and above which was built a solid stone and concrete pier, hexagonal in shape, 36 inches in diameter at the base, and battering to 26 inches at the surface of the ground. The surface mark is a copper bolt in an irregular shaped stone set in the middle of the pier even with the surface. The pier was continued with the same diameter (26 inches) to a height of 53 inches above the ground, having on its top a ⅝-inch copper bolt with a brass screw in center as a station mark. At a height of 24 inches above the surface another stone bottle was set, neck up, in the solid concrete pier.

Three other concrete piers will serve as reference marks—one bearing north 76° 47′ west (true), distant 18·36 feet; one north 79° 48′ west (true), distant 23·20 feet, and one north 5° 54′ east (true), distant 41·12 feet from the geodetic point.

Holton Base Line, Indiana, 1891.

LOCATION, MEASUREMENT, AND LENGTH.

This base is located in Ripley County, southeastern Indiana, with its middle point in latitude 39° 03′·3, and in longitude 85° 22′·2 west; the azimuth at the south end is 175° 53′·8. The length of the base is 5·50 kilometres or 3·42 statute miles nearly, and its approximate height above the sea level is 283 metres. Besides the measure of the base by a contact-slide apparatus, test measures were made with a bar-in-ice apparatus and also with metallic tapes. The last two means as applied to the measures of length being new to the Survey, a full account of the apparatus and methods employed by the observers was required, and will be found in Appendix No. 8, Coast and Geodetic Survey Report for 1892, pp. 329–503. The general charge of the measurement of the Holton Base was with Assistant A. T. Mosman, the measures and experiments with the bar-in-ice were conducted by Assistant R. S. Woodward, and the experiments with metallic tapes were intrusted to Assistants Woodward and O. H. Tittmann. In consequence of these several operations the party remained in the field during June, July, August, September, and part of October.

As the result of the office computation, a report was submitted August 23, 1894, by Assistant C. A. Schott, giving in Appendix No. 5, Coast and Geodetic Survey Report for 1894, Part 2, in a systematic and succinct manner, the final conclusions reached; hence it suffices to restrict this account to brief statements respecting the outcome of the several operations.

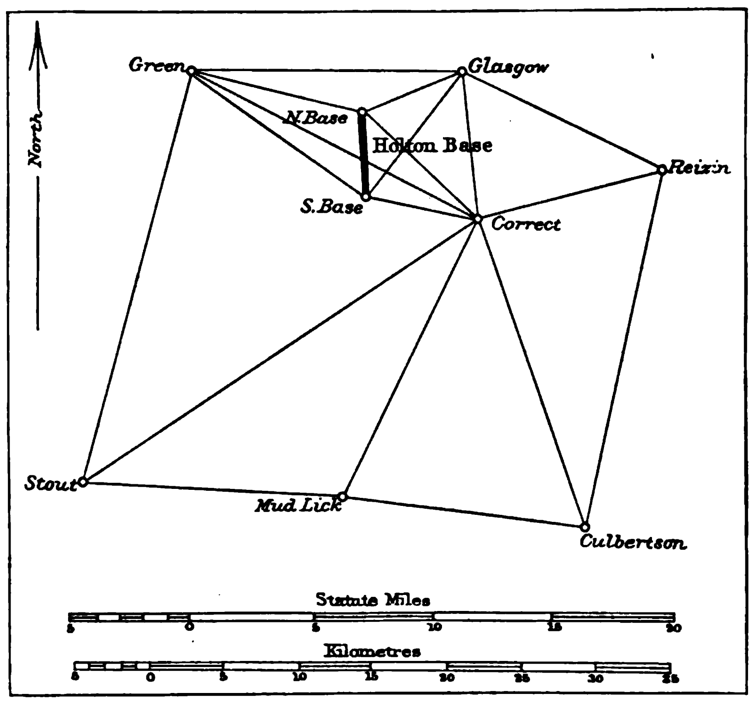
The site of the base was selected by Assistant Mosman in October and November, 1890; it is on a nearly level tableland between the villages of Holton and New Marion. The line passes over grassy soil and plowed fields, and in part through woods. At certain places and times the ground was found wet and springy. Its elevation was obtained by spirit-level with the line of levels from Sandy Hook, New Jersey.

The whole length of the base was measured twice with the contact-slide apparatus, 5-metre steel rods Nos. 13 and 14, once forward and once backward; two extra measures were made of part of it. One kilometre of the base was measured four times with the

bar-in-ice apparatus and its 5-metre steel bar No. 17. There were made besides for each of the six sections of the base from 6 to 30 steel tape measures, those over the bar-in-ice kilometre being quite numerous.

The terminals of the base are marked by stone monuments, in which are inserted copper bolts with cross lines on their tops. The subsurface mark is a bolt in a limestone post. Section stones were set at 1·2, 2·1, 3, 4, and 5 kilometres from South Base, also at 3·9 and 4·9, for the measure of a kilometre with the bar-in-ice. At the camp near Holton there was also established under a covered shed a standard 100-metre line or hectometre, and repeatedly measured with the same apparatus for the purpose of testing the combined length of the 5-metre contact-slide bars and of standardizing the metallic tapes.

No. 9.



Length of the 5-metre steel bar No. 17.—This being the bar, when immersed in melting ice, to serve for the determination of the lengths of the rods Nos. 13 and 14, the first step taken was to find its value in terms of the International Prototype Metre, for which latter No. 21 was selected. We have the following results from elaborate series of observations made at Washington under different conditions by observers Woodward, Tittmann, and Siebert. Both No. 17 and No. 21 are line measures.

Date.	Length of B_{17} at 0° C.
July, 1891 (in office vault)	$5m-11{\cdot}0\mu\pm1{\cdot}4\mu$
February and March, 1892 (in vault)	$5m-15{\cdot}4\mu\pm0{\cdot}7\mu$
April to May, 1892 (in vault)	$5m-11{\cdot}7\mu\pm1{\cdot}8\mu$
July and August, 1892 (on field comparator south of office building)	$5m-16{\cdot}6\mu\pm0{\cdot}4\mu$
Weighted Mean	$5m-16{\cdot}2\mu\pm0{\cdot}4\mu$*

It was noted, however, that for Woodward and Siebert, observers, there obtained an effect of a personal equation which made the length $5m - 18{\cdot}0\mu \pm 1{\cdot}3\mu$.

* When referred to the International Metre, this probable error must be increased to $\pm$ 1·1μ (Report of 1894, p. 391).

Determination of the coefficient of expansion of rods Nos. 13 and 14.—Observations were made for this purpose in the office vault by Assistant Tittmann and Mr. L. A. Fischer, in May, 1891, with the following results:

For rod No. 13	0·000 011 776 $\pm$ 27	for the centigrade scale
14	0·000 011 714 $\pm$ 29	

The length of the 5-metre contact-slide rods Nos. 13 and 14.—Four different determinations were made, two or three of which were of a confirmatory character only.

(a) Comparisons in the vault at Washington, of Nos. 13 and 14 with No. 17 in melting ice, observers Woodward and Tittmann, July, 1891. Whence

$$\text{No. } 13 = 5m. + 1\ 278\mu \pm 4 \text{ and No. } 14 = 5m + 1\ 297\mu \pm 3, \text{ at the temperature } 22^\circ{\cdot}2 \text{ C.}$$

and using for the length of No. 17 the Woodward-Siebert value.*

(b) Comparisons of the combined length or of Σ (13 and 14) made at the hectometre line in the Holton camp, observers Woodward and Siebert (July to October, 1891). Twelve measures of this line were made with No. 17 and twenty-one, by Mr. Tittmann, with the rods Nos. 13 and 14 under a variety of conditions. Whence we get

$$\Sigma\,(13 + 14) = 10m + 2{\cdot}608mm \pm 5 \text{ at } 22^\circ{\cdot}2 \text{ C.}$$

(c) Comparisons of $\Sigma\,(13 + 14)$ at north end hectometre of the Holton Base. Four measures were had with No. 17 and thirteen measures with the two rods, in September, 1891. Whence we get

$$\Sigma\,(13 + 14) = 10m + 2{\cdot}609mm \pm 6 \text{ at } 22^\circ{\cdot}2 \text{ C.}$$

(d) Comparison of the $\Sigma\,(13 + 14)$ at the Holton Base kilometre 3·9 to 4·9. This distance was measured 4 times with No. 17 and 6 times with the rods in August and September, 1891. Whence we have for the above temperature

$$\Sigma\,(13 + 14) = 10m + 2{\cdot}618mm. \pm 5\,(?)$$

The value finally adopted is

$$10m + 2{\cdot}610mm \pm 5 \text{ at } 22^\circ{\cdot}2 \text{ C.}$$

The measurement of the base.—The measurement of the base proper with rods Nos. 13 and 14 was made between July 28 and August 13, 1891, Assistant Tittmann being aided by Mr. J. F. Hayford and part of the time by Prof. J. H. Gore. Special measures were continued up to October 6. Pages 110 to 114 of the Coast and Geodetic Survey Report for 1894 (part 2) give all needful information respecting the results in detail. The following two tables showing the discrepancies of the forward and backward measures of subdivisions of the base are taken from that publication.

* When joining these rods, their combined length must be increased by 0·030 millimetre for slant of knife-edges.

Section of base.		Forward measure.	Backward measure.	Difference.
		m.	*m.*	*mm.*
S. Base to 66th bar		330·002 4	330·001 8	+0·6
66	139	364·946 2	364·943 9	+2·3
139	240	505·075 8	505·077 2	−1·4
240	420	899·964 5	899·968 4	−3·9
420	600	900·063 9	900·063 6	+0·3
600	780	900·018 7	900·021 4	−2·7
780	800	99·995 9	99·994 2	
780	800	·993 4	·991 7	
Mean.		·994 6	·993 0	+1·6
(800)	(875)	(374·874 7	374·875 1	(−0·4)
(875)	(980)	(525·128 1	525·125 4)	(+2·7)
Sum.		900·002 8	900·000 5	+2·3
800	980	900·004 9	900·001 7	+3·2
Mean.		900·003 8	900·001 1	+2·7
980	1 000	99·945 1	99·946 0	−0·9
1 000 to N. Base		500·799 4	500·799 4	0·0
Σ		5 500·814 4	5 500·815 8	−1·4
Mean		5 500·815 1		

The above tabular results when further condensed become as follows:

Bar number.		Number of bars.	Length.	Forward.	Backward.	Difference.
			m.	*mm.*	*mm.*	*mm.*
S. B. to	240	240	1 200	+ 24·4	+ 22·9	+1·5
240	420	180	900	− 35·5	− 31·6	−3·9
420	600	180	900	+ 63·9	+ 63·6	+0·3
600	780	180	900	+ 18·7	+ 21·4	−2·7
780	980	200	1 000	− 1·5	− 6·0	+4·5
980	N. B.	120	600	+744·5	+745·4	−0·9
Σ			5 500	+814·5	+815·7	−1·2

This difference for the space 780 to 980 is derived from the several measures involved.

The length of the base, 5 500·815 metres, given above is yet to be corrected for the small change made in the length of the combined rods, viz: − 550 × 0·01 millimetres or − 5·5 millimetres. We may also substitute the length of the base kilometre as derived from the bar-in-ice apparatus (999·996 6 metres) for the value derived from the rod measures (999·996 8); whence the length of the base, 5 500·809 metres.

For the reduction to the sea level, Mr. Siebert connected bench mark LXVII of the transcontinental line of spirit levels with North Base and the base-line levels. The north end was found 2·743 metres above the southern end and the average level 4·401 metres above the latter. We have height of North Base 281·65 metres and of the average base 283·31 metres, and adding 1·16 metres for height of bars above ground, we have

284·47 metres. From this must be subtracted 0·61 metre, a correction to the line of levels between Sandy Hook and St. Louis at mark LXVII, making the reduction to sea level = − 0·245 5 metres and the length of the base 5 500·564 metres.

Probable error of the measure with the contact-slide rods.

Let s_1 = length of first section and d_1 the difference of forward and backward measures,
s_2 = length of second section and d_2 the difference of forward and backward measures,
etc. etc.
s_n = length of n section and d_n the difference of forward and backward measures,

then the mean error of a single measure of the unit of length, here assumed one kilometre, $m_1 = \sqrt{\frac{1}{2n}\left[\frac{dd}{s}\right]}$, and the mean error of a double measure $m_{11} = \frac{1}{2}\sqrt{\frac{1}{n}\left[\frac{dd}{s}\right]}$, and the probable error of a double measure of length L becomes $r = 0·674\,5\sqrt{\frac{L}{4n}\left[\frac{dd}{s}\right]}$

We get

$$m_1 = \pm 2·01 \text{ millimetres and } r = \pm 2·24 \text{ millimetres.}$$

The probable error of $\Sigma(13 + 14)$ has been estimated at ± 0·005 millimetre, and since there are 550 double bars, the error arising from this source is ± 2·75 millimetres. The question of the relative temperature of the rods (axes) and the attached thermometers was inquired into, but the relation was too uncertain to admit of a general deduction. Whatever error may arise from this cause is included in the above value of r. Any error in the correction of the thermometers would be felt as a constant, and supposing it to be ± 0°·03 C. the effect on the base would be ± 1·94 millimetres. An uncertainty in the height of the base of ± 0·6 metre would produce an error of ± 0·53 millimetre. Combining these four probable errors, we find for the base ± 4·1 millimetres or about $\frac{1}{1\,350\,000}$ of the length.*

At the south end the triangulation station was 6 millimetres inside the line as marked by the monument. As a side of the triangulation, therefore, we have 5 500·558 metres and its logarithm 3·740 406 8.
± 4 ± 3

As already stated, certain experimental work undertaken at the Holton Base had for its object the inquiry into the practicability of applying long metallic tapes or wires for the measurement of principal base lines. The practical methods applied and the apparatus used, as well as the theory of such measures, are given in Appendix No. 8, Coast and Geodetic Survey Report for 1892, Chapter IV, pp. 413–490, and it will here suffice to exhibit the differences in length resulting from certain measures by bars and tapes. A condensed account of the facts brought out will be found in Coast and Geodetic Survey Report for 1894, part 2, pp. 114–116. At Holton two 100-metre steel tapes, supported generally at intervals of 10 metres, were standardized at the camp hectometre under given tension and temperature, and were subsequently used on the base itself. It was thought that whatever advantage and disadvantage a tape measure may have over a bar measure could here be realized; it is evident that the main advantage of the tape lies in its long unit of length and the ease with which measures of a line can be repeated when once the ground has been prepared. But to secure

* For final result see further on.

these advantages a standard length must be provided for by other means (i. e., bar measures) and the ground must be suitable for the driving of stakes and maintaining their horizontal and vertical alignment. The main uncertainty in the results from tape measures lies in the difficulty of knowing the temperature of the tapes under various atmospheric conditions during the day as well as during the night; hence what we have to fear are constant errors due to this cause.

Three measures by Assistant Woodward in August and October, 1891, with the bar-in-ice No. 17 gave the length of the camp hectometre $H_c = \overset{m.}{100{\cdot}039}\ 16$
08
01

The same distance was gone over 77 times between August 6 and October 9, 1891, with tape No. 85, and 85 times between August 1 and October 9 with tape No. 88, the temperature during these measures ranging between 32°·1 C. and 3°·5 C. The resulting lengths of the tapes were:

$$T_{85} = \overset{m.}{100{\cdot}003}\ 50 + \overset{mm.}{1{\cdot}094}\ 7\ t$$
$$T_{88} = 100{\cdot}005\ 95 + 1{\cdot}091\ 4\ t$$

with the probable error of a *single* measure of the length of the tape No. 85, $\pm 0{\cdot}17$ millimetre and of the tape No. 88, $\pm 0{\cdot}22$ millimetre. The standard lengths of the tapes being known, 30 measures of the base kilometre were made and compared with the supposed true length $K = \overset{m.}{1\ 000} - \overset{mm.}{3{\cdot}4} \pm \overset{mm.}{0{\cdot}4}$, viz:

Date. 1891.		Time of day or night.		No. of measures.	Error of measure observed—true value.
		h. m.	h. m.		mm.
Sept.	8	5 25 to	7 12 p. m.	3	+ 3·2
	23	6 27	9 32	4	− 3·0
	30	6 33	7 55	2	− 0·4
Oct.	1	6 50	8 07	2	− 0·6
	2	6 48	7 55	2	+ 2·0
	3	2 56	4 38	4	− 4·6
	7	10 02	11 31 a. m.	5	− 10·0
	8	7 44	9 58 p. m.	8	− 0·4

The day measures are considerably in error, while the night measures appear fairly correct.

The following table exhibits a comparison between the results of the bar and tape measures of the length for the several sections of the base. Two sets of results are given for the tape measures, one depending solely on night (after sundown) measures, the other depending on night and day measures and after a certain correction had been applied for the case of insolation. Some results of August 27 and 28 and all of September 4 were rejected.

Section of base line.		No. of measures.	Length of section.	Length by tapes integer metres + or —.		Bar minus tape. Night measures.
			m. mm.	*mm.*	*mm.*	*mm.*
South Base to	1·2 km.	7	1 200+ 23·6	+ 30·0	+ 30·0	− 6·4
1·2 km.	2·1 km.	8	900− 33·6	− 30·0	− 30·2	− 3·6
2·1 km.	3·0 km.	7	900+ 63·8	+ 67·7	+ 65·4	− 3·9
3·0 km.	3·9 km.	6	900+ 20·0	+ 17·0	+ 16·4	+ 3·0
3·9 km.	4·9 km.	30	1 000− 3·8	− 3·6	− 3·2	− 0·2
4·9 km.	North Base.	(12 and 7)	600+745·0	+750·9	+750·0	− 5·9
Sum			5 500+815·0	5 500 +832·0	5 500 +828·4	−17·0

From 46 tape measures, covering 6 sections of the base, the observer deduces the probable error of a measure (of a single tape) ± 0·55 millimetre, and that of the single measure of a kilometre ± 1·74 millimetres, which equals nearly $\frac{1}{575\ 000}$ part of the length; yet the length of the base from the bar and tape measures differs 17 millimetres,* that is, by its $\frac{1}{324\ 000}$ part. The observer assigns ± 3·68 millimetres for the probable error of the base from tape measures. The reduction to sea level for the tape measures is − 0·245 0 metre and the length of the base is 5 500·587 metres.

We may take the simple mean or ½ (5 500·564 + 5 500·587) or 5 500·576 ± 7·7 millimetres, where the probable error appears largely increased in consequence of the above discrepancy between the bar and tape results; it is about $\frac{1}{714\ 000}$ part of the length.

Length of base between monuments 5 500·576 ± 4 and its logarithm 3·740 408 17 ± 32

Length of base as side of triangle 5 500·570 ± 4 and its logarithm 3·740 407 70 ± 32

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE HOLTON BASE NET, 1889–90.

Holton North Base, Ripley County, Indiana. November 13 to November 18, 1890. 30-centimetre theodolite, No. 118. Telescope above ground 30·94 metres. A. T. Mosman and W. B. Fairfield, observers.

No of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
24	Glasgow	0	00	00·00	±0·12	−0·35	59·65
25	Correct	66	02	33·34	·10	+0·18	33·52
26	Holton South Base	109	00	45·41	·11	+0·16	45·57
27	Green	215	36	23·49	·19	0·00	23·49

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·70.

*And 23 millimetres as finally given.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE HOLTON BASE NET, 1889-90—continued.

Holton South Base, Ripley County, Indiana. November 6 to November 12, 1890. 30-centimetre theodolite, No. 118. Telescope above ground 30·94 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
21	Holton North Base	0	00	00·00	±0·11	−0·13	59·87
22	Glasgow	40	32	07·51	·10	−0·16	07·35
23	Correct	106	58	54·57	·12	+0·14	54·71
20	Green	308	26	09·05	·17	+0·15	09·20

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·68.

Mud Lick, Jefferson County, Indiana. August 29 to September 1, 1890. 30-centimetre theodolite, No. 118. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.				Approximate probable error.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
29	Correct	0	00	00·00	±0·14	+0·47	00·47
30	Culbertson	71	51	23·22	·11	−0·19	23·03
28	Stout	247	58	54·69	·11	−0·28	54·41

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·72.

Reizin, Ripley County, Indiana. September 21 to September 28, 1889. 30-centimetre theodolite, No. 118. Telescope above ground 35·81 metres. A. T. Mosman, observer.

No. of direction.	Objects observed.				Approximate probable error.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
3	Glasgow	0	00	00·00	±0·13	−0·14	59·86
	Tanner	161	59	13·94	·13		
	Stow	215	26	34·50	·12		
1	Culbertson	255	56	07·78	·14	−0·15	07·63
2	Correct	318	50	47·95	·12	+0·29	48·24

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·79.

Culbertson, Switzerland County, Indiana. June 7 to June 19, 1890. 30-centimetre theodolite, No. 118 Telescope above ground 35·81 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.				Approximate probable error.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
6	Reizin	0	00	00·00	±0·08	−0·42	59·58
	Stow	71	44	14·42	·11		
	Dry Ridge	96	41	06·92	·13		
4	Mud Lick	265	16	50·27	·10	−0·04	50·23
5	Correct	328	10	57·51	·10	+0·46	57·97

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·64.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE HOLTON BASE NET, 1889-90—continued.

Glasgow, Ripley County, Indiana. June 24 to July 1, November 21 to November 23, 1890. 30-centimetre theodolite, No. 118. Telescope above ground 35·81 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
15	Reizin	0 00 00·00	±0·11	−0·33	59·67
16	Correct	58 15 27·56	·09 } ·15 }	+0·51	28·07
17	Holton South Base	101 36 56·15	·11*	−0·07	56·08
18	Holton North Base	132 04 02·37	·17*	+0·41	02·78
19	Green	154 19 54·47	·13	−0·52	53·95

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·77.

* The directions marked by a * depend on the probable error ± 0″·15 of "Correct" during the second occupation.

Correct, Ripley County, Indiana. July 3 to August 27, and November 25 to November 30, 1890. 30-centimetre theodolite, No. 118. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
7	Glasgow	0 00 00·00	±0·08 } ·18 }	−0·23	59·77
8	Reizin	80 35 19·93	·11	+0·15	20·08
9	Culbertson	165 51 38·47	·15	+0·11	38·58
10	Mud Lick	211 06 09·57	·16	−0·49	09·08
11	Stout	241 49 02·23	·14	+0·84	03·07
12	Holton South Base	289 48 14·74	·16*	+0·22	14·96
13	Green	303 52 33·77	·12	−0·41	33·36
14	Holton North Base	319 51 08·37	·16*	−0·19	08·18

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·84.

* The directions marked by a * depend on the probable error ± 0″·18 of "Glasgow" during the second occupation.

Stout, Jefferson County, Indiana. August 29 to September 13, 1890. 30-centimetre theodolite, No. 147. Telescope above ground 41·91 metres. J. B. Boutelle, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
	Tripp	0 00 00·00	±0·13		
36	Green	32 33 05·72	·24	+0·14	05·86
37	Correct	74 01 21·01	·20	−0·17	20·84
38	Mud Lick	111 17 21·59	·22	+0·03	21·62
	Holman	224 28 07·36	·32		
	Miller	287 48 14·96	·26		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·38.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE HOLTON BASE NET, 1889-90—completed.

Green, Jennings County, Indiana. July 11 to August 14, and November 19 to November 20, 1890. 30-centimetre theodolites, Nos. 118 and 147. Telescope above ground 46.79 metres. J. B. Boutelle and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
	Tripp	0	00	00.00	±0.12		
	Weed Patch	49	57	43.52	.20		
31	Glasgow	222	13	20.09	.16	+0.15	20.24
32	Holton North Base	235	33	52.93	.22	+0.10	53.03
33	Correct	250	01	28.54	.20	−0.15	28.39
34	Holton South Base	257	24	24.18	.18	+0.41	24.59
35	Stout	326	29	45.14	.20	−0.51	44.63

Probable error of a single observation of a direction (D. and R.) $= \pm 1''.15$.

FIGURE ADJUSTMENT.

*Observation equations.**

No.	
1	$0 = +0.17 + (14) - (12) + (23) - (21) + (26) - (25)$
2	$0 = +0.73 + (7) - (12) + (23) - (22) + (17) - (16)$
3	$0 = +0.13 + (34) - (32) + (27) - (26) + (21) - (20)$
4	$0 = +0.50 + (34) - (31) + (19) - (17) + (22) - (20)$
5	$0 = +1.33 + (24) - (27) + (32) - (31) + (19) - (18)$
6	$0 = +1.14 + (33) - (31) + (19) - (16) + (7) - (13)$
7	$0 = -0.78 + (3) - (2) + (8) - (7) + (16) - (15)$
8	$0 = +0.49 + (6) - (5) + (9) - (8) + (2) - (1)$
9	$0 = +1.93 + (37) - (36) + (35) - (33) + (13) - (11)$
10	$0 = -2.28 + (29) - (28) + (38) - (37) + (11) - (10)$
11	$0 = +0.76 + (30) - (29) + (10) - (9) + (5) - (4)$
12	$0 = +4.5 - 0.76(7) - 2.88(12) + 3.64(14) - 2.23(16) + 5.81(17) - 3.58(18) + 0.73(24) + 2.26(25) - 2.99(26)$
13	$0 = +2.1 + 1.98(17) - 3.58(18) + 1.60(19) + 0.73(24) - 1.36(26) + 0.63(27) + 2.98(31) - 5.25(32) + 2.27(34)$
14	$0 = +13.9 - 0.76(7) - 7.64(12) + 8.40(13) - 2.23(16) + 3.83(17) - 1.60(19) - 2.98(31) + 16.25(33) + 13.27(34)$
15	$0 = -3.4 - 1.07(1) + 3.48(2) - 2.41(3) - 1.08(4) + 4.47(5) - 3.39(6) - 1.30(15) + 1.07(16) + 0.23(19) + 0.85(28) - 0.16(29) - 0.69(30) - 3.99(31) + 4.50(33) - 0.51(35) - 2.39(36) + 5.16(37) - 2.77(38)$

* The net contains 11 angle and 4 side equations; the coefficients in the latter refer to the sixth place in the log s.

FIGURE ADJUSTMENT—continued.

Correlate equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
(1)								−1							−1·07
(2)							−1	+1							+3·48
(3)							+1								−2·41
(4)											−1				−1·08
(5)	...	...	...	...	...	...	...	−1	...	...	+1	......	......	....	+4·47
(6)								+1							−3·39
(7)		+1				+1	−1					−0·76		- 0·76	
(8)							+1	−1							
(9)								+1			−1				
(10)	...	...	...	...	...	...	...	...	...	−1	+1	......	......	....	......
(11)									−1	+1					
(12)	−1	−1										−2·88		−7·64	
(13)						−1			+1					+8·40	
(14)	+1											+3·64			
(15)	...	...	...	...	...	...	−1	...	...	...	...	......	......	....	−1·30
(16)		−1				−1	+1					−2·23		−2·23	+1·07
(17)		+1		−1								+5·81	+1·98	+3·83	
(18)					−1							−3·58	−3·58		
(19)				+1	+1	+1							+1·60	−1·60	+0·23
(20)	...	...	−1	−1	...	...	...	...	...	...	...	......	......	....	......
(21)	−1		+1												
(22)		−1		+1											
(23)	+1	+1													
(24)					+1							+0·73	+0·73		
(25)	−1	...	...	...	...	...	...	...	...	...	...	+2·26	......	......	......
(26)	+1		−1									−2·99	−1·36		
(27)			+1		−1								+0·63		
(28)										−1					+0·85
(29)										+1	−1				−0·16
(30)	...	...	...	...	...	...	...	...	...	...	+1	......	......	......	−0·69
(31)				−1	−1	−1							+2·98	−2·98	−3·99
(32)			−1		+1								−5·25		
(33)						+1			−1					+16·25	+4·50
(34)			+1	+1									+2·27	−13·27	
(35)	...	...	...	...	...	...	...	...	+1	...	...	......	......	....	−0·51
(36)									−1						−2·39
(37)									+1	−1					+5·16
(38)										+1					−2·77

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}S
0 = +0·17	+6	+2	−2									+1·27	−1·36	−7·64	
+0·73		+6		−2		+2	−2					+10·16	+1·98	+12·94	−1·07
+0·13			+6	+2	−2							+2·99	+9·51	−13·27	
+0·50				+6	+2	+2						−5·81	−1·09	−15·72	+4·22
+1·33	.	.	.	.	+6	+2						+4·31	−2·95	+1·38	+4·22
+1·14						+6	−2		−2			+1·47	−1·38	+10·70	+7·65
−0·78							+6	−2				−1·47		−1·47	+3·52
+0·49								+6			−2				−3·31
+1·93									+6	−2				−7·85	+2·54
−2·28	.	.	.	.	.	.	.	.	.	+6		.	.	.	−8·94
+0·76											+6				+5·02
+4·5												+88·25	+28·92	+49·80	−2·39
+2·1													+63·67	−33·98	−11·52
+13·9														+600·74	+82·25
−3·4															+132·25

Resulting values of correlates.

$C_1 = -0.186$	$C_6 = -0.422$	$C_{11} = -0.101$
$C_2 \quad +0.322$	$C_7 \quad +0.164$	$C_{12} \quad -0.0012$
$C_3 \quad -0.313$	$C_8 \quad +0.010$	$C_{13} \quad -0.0229$
$C_4 \quad +0.162$	$C_9 \quad -0.448$	$C_{14} \quad -0.0463$
$C_5 \quad -0.329$	$C_{10} \quad +0.388$	$C_{15} \quad +0.1281$

Corrections to angular directions.

″	″	″	″
(1) = −0.147	(11) = +0.836	(21) = −0.127	(31) = +0.148
(2) +0.292	(12) +0.221	(22) −0.160	(32) +0.104
(3) −0.145	(13) −0.415	(23) +0.136	(33) −0.150
(4) −0.037	(14) −0.190	(24) −0.347	(34) +0.411
(5) +0.462	(15) −0.331	(25) +0.183	(35) −0.513
(6) −0.424	(16) +0.507	(26) +0.162	(36) +0.142
(7) −0.228	(17) −0.070	(27) +0.002	(37) −0.175
(8) +0.154	(18) +0.415	(28) −0.279	(38) +0.033
(9) +0.111	(19) −0.522	(29) +0.469	
(10) −0.489	(20) +0.151	(30) −0.189	

Check $\begin{cases} \Sigma \text{ of } + \text{ corrections } 4.939, \\ \Sigma \text{ of } - \text{ corrections } 4.938 \end{cases}$ also $\Sigma p v v = +3.758,$ $-\Sigma \omega C = +3.756$

Mean error of an observed *direction* $m_1 = \sqrt{\frac{[pvv]}{n}} = \pm 0''.50$ where n = number of conditions, and mean error of an angle $m_{\angle} = m_1\sqrt{2} = \pm 0''.71$, also probable error of the same $\pm 0''.48$.

TRIANGLES OF THE HOLTON BASE NET, INDIANA.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
1	Correct	30	02	53.63	−0.41	53.22	0.03	3.740 407 7	5 500.570
	Holton South Base	106	58	54.57	+0.26	54.83	0.03	4.021 444 9	10 506.18
	Holton North Base	42	58	12.07	−0.02	12.05	0.04	3.874 346 0	7 487.66
				00.27			0.10		
2	Glasgow	43	21	28.59	−0.58	28.01	0.06	3.874 346 0	7 487.66
	Correct	70	11	45.26	−0.45	44.81	0.06	4.011 195 8	10 261.14
	Holton South Base	66	26	47.06	+0.30	47.36	0.06	3.999 893 9	9 997.56
				00.91			0.18		
3	Glasgow	73	48	34.81	−0.10	34.71	0.05	4.021 444 9	10 506.18
	Correct	40	08	51.63	−0.04	51.59	0.06	3.848 417 4	7 053.71
	Holton North Base	66	02	33.34	+0.53	33.87	0.06	3.999 893 9	9 997.56
				59.78			0.17		
4	Glasgow	30	27	06.22	+0.48	06.70	0.03	3.740 407 7	5 500.570
	Holton South Base	40	32	07.51	−0.04	07.47	0.03	3.848 417 4	7 053.71
	Holton North Base	109	00	45.41	+0.51	45.92	0.03	4.011 195 8	10 261.14
				59.14			0.09		

TRIANGLES OF THE HOLTON BASE NET, INDIANA—continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
5	Green	13	20	32·84	−0·04	32·80	0·04	3·848 417 4	7 053·71
	Glasgow	22	15	52·10	−0·94	51·16	0·04	4·063 736 7	11 580·75
	Holton North Base	144	23	36·51	−0·35	36·16	0·04	4·250 322 2	17 795·99
				01·45			0·12		
6	Green	27	48	08·45	−0·30	08·15	0·15	3·999 893 9	9 997·56
	Glasgow	96	04	26·91	−1·03	25·88	0·15	4·328 671 1	21 314·30
	Correct	56	07	26·23	+0·19	26·42	0·15	4·250 322 4	17 796·00
				01·59			0·45		
7	Green	35	11	04·09	+0·26	04·35	0·12	4·011 195 8	10 261·14
	Glasgow	52	42	58·32	−0·45	57·87	0·12	4·151 332 3	14 168·78
	Holton South Base	92	05	58·46	−0·31	58·15	0·13	4·250 322 4	17 796·00
				00·87			0·37		
8	Green	14	27	35·61	−0·25	35·36	0·06	4·021 444 9	10 506·18
	Holton North Base	149	33	50·15	−0·18	49·97	0·05	4·328 671 1	21 314·30
	Correct	15	58	34·60	+0·23	34·83	0·05	4·063 736 9	11 580·75
				00·36			0·16		
9	Green	21	50	31·25	+0·31	31·56	0·05	3·740 407 7	5 500·570
	Holton North Base	106	35	38·08	−0·16	37·92	0·05	4·151 332 3	14 168·78
	Holton South Base	51	33	50·95	−0·28	50·67	0·05	4·063 736 8	11 580·75
				00·28			0·15		
10	Green	7	22	55·64	+0·56	56·20	0·04	3·874 346 0	7 487·66
	Correct	14	04	19·03	−0·64	18·39	0·03	4·151 332 3	14 168·78
	Holton South Base	158	32	45·52	−0·01	45·51	0·03	4·328 671 1	21 314·30
				00·19			0·10		
11	Reizin	41	09	12·05	−0·44	11·61	0·11	3·999 893 9	9 997·56
	Correct	80	35	19·93	+0·38	20·31	0·10	4·175 733 8	14 987·66
	Glasgow	58	15	27·56	+0·99	28·40	0·11	4·111 254 5	12 919·76
				59·54			0·32		
12	Culbertson	31	49	02·49	−0·89	01·60	0·24	4·111 254 5	12 919·76
	Correct	85	16	18·54	−0·04	18·50	0·23	4·387 791 5	24 422·58
	Reizin	62	54	40·17	+0·44	40·61	0·24	4·338 809 3	21 817·72
				01·20			0·71		
13	Mud Lick	71	51	23·22	−0·66	22·56	0·26	4·338 809 3	21 817·72
	Correct	45	14	31·10	−0·60	30·50	0·27	4·212 268 2	16 303·03
	Culbertson	62	54	07·24	+0·50	07·74	0·27	4·310 460 5	20 439·04
				01.56			0·80		

TRIANGLES OF THE HOLTON BASE NET, INDIANA—completed.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
14	Stout	41	28	15·29	−0·32	14·97	0·50	4·328 671 1	21 314·30
	Green	76	28	16·60	−0·36	16·24	0·50	4·495 436 5	31 292·23
	Correct	62	03	31·54	−1·25	30·29	0·50	4·453 827 3	28 433·30
				03·43			1·50		
15	Stout	37	16	00·58	+0·21	00·79	0·28	4·310 460 5	20 439·04
	Correct	30	42	52·66	+1·32	53·98	0·28	4·236 549 3	17 240·48
	Mud Lick	112	01	05·31	+0·75	06·06	0·27	4·495 436 6	31 292·24
				58·55			0·83		

PROBABLE ERRORS.

Determination of the probable errors of the length of the sides common to the net and to the adjacent chains of triangulation.

For the side Reizin to Culbertson, as adjusted, we make use of the expression—

$$\frac{\text{Reizin to Culbertson}}{\text{Holton Base}} = \frac{\sin(9-8)\sin(16-15)\sin(25-24)\sin(23-21)}{\sin(6-5)\sin(3-2)\sin(18-16)\sin(14-12)}$$

hence the function:

$$F = \log\sin(9-8) + \log\sin(16-15) + \log\sin(25-24) + \log\sin(23-21) - \log\sin(6-5) - \log\sin(3-2) - \log\sin(18-16) - \log\sin(14-12)$$

Establishing and solving the transfer equations, we find the reciprocal of the weight $\frac{1}{P} = 17·776$, also the mean error m_F and the probable error r_F, both expressed in units of the sixth place of decimals in their logarithms, viz: $\pm 2·12$ and $\pm 1·43$, respectively; hence log. distance Reizin to Culbertson $4·387\ 791\ 5 \pm 1\ 4$ and the distance $24\ 422·58 \pm 0·08$ metres. The probable error is about $\frac{1}{300\ 000}$ part of the length.

To this we have to add the proportional error depending upon that of the base measure, or $0·0041 \times \frac{24\ 423}{5\ 501} = \pm 0·018$ metre; hence probable error of length of side Reizin to Culbertson,

$$\sqrt{(0·08)^2 + (0·018)^2} = \pm 0·082 \text{ metre.}$$

For the side Green to Stout, we use the expression—

$$\frac{\text{Green to Stout}}{\text{Holton Base}} = \frac{\sin(23-21)\sin(27-25)\sin(13-11)}{\sin(14-12)\sin(33-32)\sin(37-36)}$$

$$F = \log\sin(23-21) + \log\sin(27-25) + \log\sin(13-11) - \log\sin(14-12) - \log\sin(33-32) - \log\sin(37-36)$$

Establishing and solving the transfer equations, we get $\frac{1}{P} = 14·783$, also $m_F = \pm 1·93$

and $r_F = \pm 1{\cdot}30$; hence log. distance Green to Stout $\underset{\pm \quad 1\ 3}{4{\cdot}453\ 827\ 3}$ and distance $\underset{\pm\ 0{\cdot}085}{28\ 433{\cdot}30}$ metres. The probable error is about $\frac{1}{335\ 000}$ part of the length; combining with this the proportional error due to the base measure, or $0{\cdot}004\ 1 \times \frac{28\ 433}{5\ 501} = \pm 0{\cdot}021$ metre, we get probable error of length of side Green to Stout—

$$\sqrt{(0{\cdot}085)^2 + (0{\cdot}021)^2} = \pm 0{\cdot}09 \text{ metre.}$$

GENERAL DESCRIPTION OF STATIONS FORMING HOLTON BASE NET, INDIANA.

Holton South Base, Ripley County; established in 1890 by A. T. Mosman. This station is situated in the northwest corner of section 25, township 7 north, range 10 east of the second principal meridian, in Center Township, about 1½ miles north of the village of New Marion. The geodetic point is marked as follows: The underground mark is a fine drill hole one-fourth inch deep at the intersection of cross lines cut on a copper bolt set in the top of a limestone post 6 inches square and 2 feet long, its top being 3 feet below the surface. Above and around this post, except for a space of 1 foot square immediately over it, is a layer of concrete 1 foot thick and 4 feet square, which serves as a foundation for the surface monument, consisting of a limestone block composed of two parts firmly cemented together, 3 feet square and 30 inches high, projecting 6 inches above the surface. The upper part is beveled to 24 inches square, and a fine drill hole at the intersection of cross lines cut on a copper bolt set in the top marks the geodetic point at the surface. On this surface monument was placed a limestone shaft 3 feet high, 2 feet square at the base, and 1 foot square at the top, having the following inscriptions cut on three of its faces: On the south face, "U. S. COAST AND GEODETIC SURVEY;" on the east face, "SOUTH BASE," and on the west face, "HOLTON BASE LINE, 1891." As reference marks, four stone posts, each 6 inches square and 2 feet long, with copper bolt on the top, were set as follows: One about northwest, on the fence line on the south side of the public road, distant 54·80 feet; one about northeast, on the same fence line, distant 51·60 feet; one about southeast, distant 38·55 feet, and one about southwest, distant 42·71 feet from the geodetic point, forming a square 65·62 feet on each side.

Holton North Base, Ripley County; established in 1890 by A. T. Mosman. This station is in the southeast corner of section 2, township 7 north, range 10 east of the second principal meridian, on land of Mr. Sam Cox, in Otter Creek Township, about 1 mile east of Holton, on the south side of the Ohio and Mississippi Railroad, and distant 94·82 feet from the south rail of the track. The markings and monuments at the geodetic points are exactly similar in every respect to those at South Base, with the exception of the inscription on one end of the faces of the upper limestone shaft, NORTH being substituted for SOUTH. As reference marks, four stone posts, each 6 inches square and 2 feet long, with copper bolt on the top, were set as follows: One on the line to South Base, distant 49·24 feet; one in prolongation of the base line northward, distant 49·05 feet; one at right angle to the eastward and one at right angle to the westward, each distant 49·21 feet from the geodetic point, forming a square 69·5 feet on each side.

Correct, Ripley County; established in 1887 by F. W. Perkins. This station is situated in the southwest corner of the southeast quarter of the southeast quarter of section 27, township 7 north, range 11 east of the second principal meridian, Johnson Township. It is nearly on the line dividing sections 27 and 34, and 40 feet west of the county road running from Versailles to Correct, Versailles being 14 miles north and Correct P. O. a half mile south of the station. The geodetic point is marked by the apex of an earthenware pyramid buried 3 feet below the surface, over which is placed a tile drain pipe 6 inches in diameter and 2¼ feet long, filled with cement concrete, and having a 6-inch spike in the center of the top as a surface mark. The hole around this pipe was filled with concrete so that the pyramid is covered with a solid block of concrete 2¼ feet high and 30 inches in diameter, with the drain pipe in its center. Four 4-inch tile drain pipes, filled with concrete with nails in the center, were placed as follows, as reference marks: Two to the eastward of the station; one on the west side of the road, distant 23·85 feet; and one on the east side of the road, distant 65·11 feet; and one south on the fence line, distant 30·23 feet; and the fourth one just inside of the fence line on the west side of the road, distant 66·43 feet, and bearing north 40° 43′ east from the geodetic point.

Glasgow, Ripley County; established in 1887 by F. W. Perkins. This station is situated in the southeast quarter of the southeast quarter of section 28, township 8 north, range 11 east of the second principal meridian, 584 feet north and 94¼ feet west of the section corner. It is on the land of Ashman and Glasgow, about 1¼ miles south of the town of Osgood, on the west side of the road running from that town to the stone quarries of the above firm, but beyond the quarries. The geodetic point is marked by the apex of an earthenware pyramid sunk 3 feet below the surface, over which is placed a section of drain-tile pipe 6 inches in diameter and 2¼ feet long, reaching to the surface and filled with concrete. The hole around the pipe, 18 inches in diameter, is also filled with concrete, making a solid block of concrete with the pipe in the center. As reference marks, four 4-inch pipes filled with concrete were set as follows: Three on the western line of the road, one bearing north 46° 45′ east (true), distant 100·5 feet, one bearing east 1° 37′ south, distant 75·34 feet, and one bearing south 51° 17′ east, distant 91·55 feet from the geodetic point; the fourth one is on the eastern line of the road (which runs along the section line between sections 27 and 28), bearing east 1° 37′ south, and distant 112·94 feet from the geodetic point.

Green, Jennings County; established in 1887 by F. W. Perkins. This station is situated in Columbia Township, near the northeast corner of section 34, township 8 north, range 9 east of the second principal meridian, and is distant 927 feet west and 61 feet south from the section corner stone. It is on land belonging to Samuel Rush, about 5 miles north of the town of Butlerville, on the Ohio and Mississippi Railroad, and about 2 miles southwest of the town of Zenas. The geodetic point is marked by the apex of an earthenware pyramid buried 3 feet below the surface. Over this is a terra-cotta drain pipe, 6 inches in diameter and 2 feet long, filled with cement and projecting about 2 inches above the surface. The letters U.S. are marked on the cement and a nail inserted head downward in the cement at the top of the pipe serves as a surface mark. As reference marks, three 4-inch drain pipes, filled with cement with nail in center, were set in the fence line north of station, their tops projecting 2 inches above the ground; the western one distant 69 feet 4 inches, the northern one distant 42 feet 11 inches, and the eastern one distant 67 feet from the geodetic point.

Reizin, Ripley County; established in 1887 by F. W. Perkins. This station is situated about 1 mile east of the town of Elrod, and about 320 yards south of the road from Elrod to Dillsboro, on land belonging to Mr. Joseph Beall, 39 feet east of the line fence dividing the lands of Mr. Beall from those of Mr. Reizin Johnson. The geodetic point is marked by the apex of an earthenware pyramid buried 3½ feet below the surface, over which is placed 4 inches of soil, then 3 inches of blacksmith's cinder from the forge, then 3 inches more of soil; over this is placed a solid shaft of concrete 20 inches high and about 16 inches in diameter, having embedded in its center a drain-tile pipe 6 inches in diameter and 2 feet long, filled with cement, the top even with the surface and having a spike in the center to mark the geodetic point.

As reference marks, four 4-inch drain-tile pipes, filled with cement and nails in the center, were set as follows: One true north, distant 5·98 feet; one true south, distant 5·96 feet; one true east, distant 6·05 feet, and one true west, distant 39·2 feet from the geodetic point. A hickory tree standing alone in the field, bearing north 24° 11′ east, and distant 181·3 feet from the center mark, was blazed and marked with a triangle of small nails and a large one in the center, as an additional reference mark.

Culbertson, Switzerland County; established in 1887 by F. W. Perkins. This station is situated in the northwest corner of the southeast quarter of section 33, township 5 north, range 12 east of the second principal meridian in Pleasant Township, on land of James Culbertson. It is about 11 miles northerly from the town of Vevay on the Ohio River. It is on the highest part of the pasture just east of Culbertson's house, about 700 feet from the pike and 48 feet east of center of country road running south from the pike. The geodetic point is marked by the apex of an earthenware pyramid buried 3 feet below the surface, over which is placed a concrete block 18 inches in diameter by 2¼ feet long, having embedded in its center a drain-tile pipe 6 inches in diameter, with a nail at the intersection of cross lines on top as a surface mark. As reference marks, four 4-inch drain-tile pipes were set in concrete in a similar manner: One due north, distant 5·92 feet; one due east, distant 6·12 feet; one due south, distant 5·93 feet, and one due west, 35·63 feet distant from the geodetic point. The west pipe is in the fence line on east side of road.

Mud Lick, Jefferson County; established in 1887 by F. W. Perkins. This station is situated in the southeast corner of the northwest quarter of section 26, township 5 north, range 10 east of the second principal meridian, on land of Mr. W. H. Buckhannon. It is on the west side of the Michigan road, about one-half mile south of Mud Lick post-office and 7 miles from Madison, a town on the Ohio River, and just north of a county road running west to Lancaster. The geodetic point is marked by the apex of an earthenware pyramid buried 3 feet below the surface, over which is placed a solid concrete block 2 feet in diameter and 2¼ feet high, having embedded in its center a drain-tile pipe, 6 inches by 2¼ feet, filled with concrete. The letters U.S.C.S. are marked on top, and a 6-inch spike at the intersection of cross lines marks the point at the surface. As reference marks, four 4-inch drain-tile pipes filled with cement were set as follows: One nearly east, distant 165·5 feet; one nearly southeast, distant 189·7 feet; and two nearly south, one 107·4 feet and the other 144·9 feet distant from the geodetic point.

Stout, Jefferson County; established in 1887 by F. W. Perkins. This station is situated near the northeast corner of section 25, township 5 north, range 8 east of the

second principal meridian, on land of Mr. A. O. Stout, who lives about one-third mile south of the station. It is about 5 miles southwest of the town of Dupont and the same distance northeast of the town of Paris, and about 1 mile north of Neils Creek post-office. The section line a few feet north of the station is the boundary line between Jefferson and Jennings counties. The geodetic point is marked by the apex of an earthenware pyramid buried 3 feet below the surface, over which is placed a drain-tile pipe, 6 inches in diameter and 2·5 feet long, filled with cement, the top projecting about 1 inch above the surface, and having the letters U.S. cut in the cement, and a nail in the center as a surface mark. Three drain-tile pipes, 3 inches by 2·5 feet, filled with cement and a nail in the center, with the numbers 1, 2, and 3 cut in the cement, were set as follows, for reference marks: No. 1, bearing south 43° 12′ west, distant 40·95 feet; No. 2, bearing south 86° 48′ west, distant 27·72 feet, and No. 3, bearing north 36° 41′ west, distant 45·94 feet from the geodetic point. They were placed in the fence line west of the station. An additional reference mark is the quarter-section stone marking the northwest corner of the northeast quarter of the northeast quarter of section 25, which bears north 39° 55′ west and is 43·16 feet distant from the geodetic point. The above bearings are magnetic.

(*g*) *St. Albans Base Line, West Virginia, 1892.*

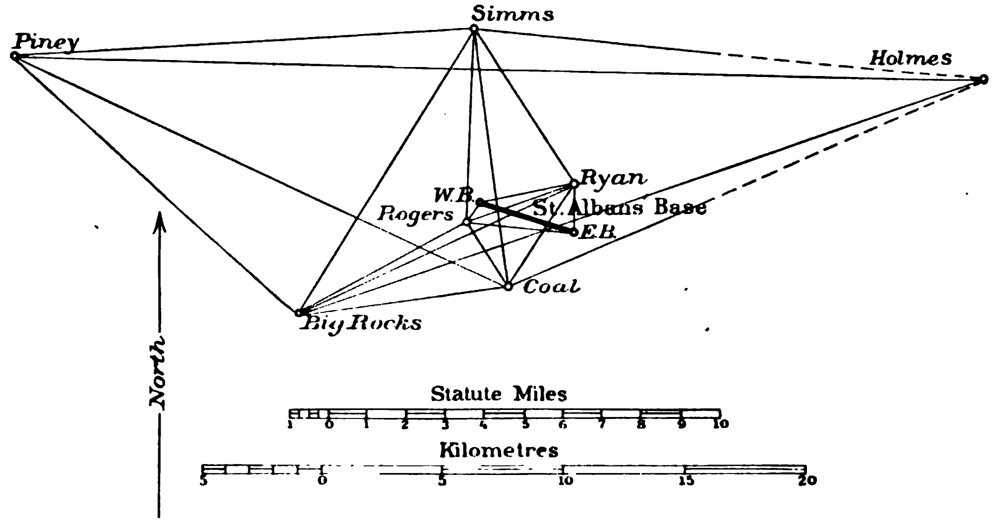
LOCATION, MEASUREMENT, AND LENGTH.

This base is situated in the valley of the Great Kanawha River, near the village of St. Albans, in Kanawha County, West Virginia. The middle point of the base is in latitude 38° 23′·0 and in longitude 81° 48′·9 west of Greenwich; the azimuth east end to west end is 108° 03′·9. The length of the base is nearly 3·87 kilometres or 2·40 statute miles; its elevation above the ocean is about 180 metres. This is the second base of precision the measure of which was effected by means of metallic tapes, and the first one where the tape measures were accepted exclusive of other means. The experimental work at the Holton Base of 1891 (see account of that base) seemed to prove that tape measures could be depended upon for refined results in those cases where the requisite close attention is paid to all circumstances and to minute details which have or may have an influence on the result. Among these influences the condition of the atmosphere is the most potent, and measures made after sundown or during nighttime were considered more favorable than those taken in daytime and during sunshine. For a comprehensive understanding of the use of tapes for the above purpose, no better reference need be given than the report of Assistant R. S. Woodward, by whom the method was developed on the survey (see Appendix No. 8, Coast and Geodetic Survey Report for 1892, part 2, pp. 453–489). This also includes his account of the St. Albans Base. A more condensed paper of the results as reviewed by the office is given in Appendix No. 6, Coast and Geodetic Survey Report for 1894.

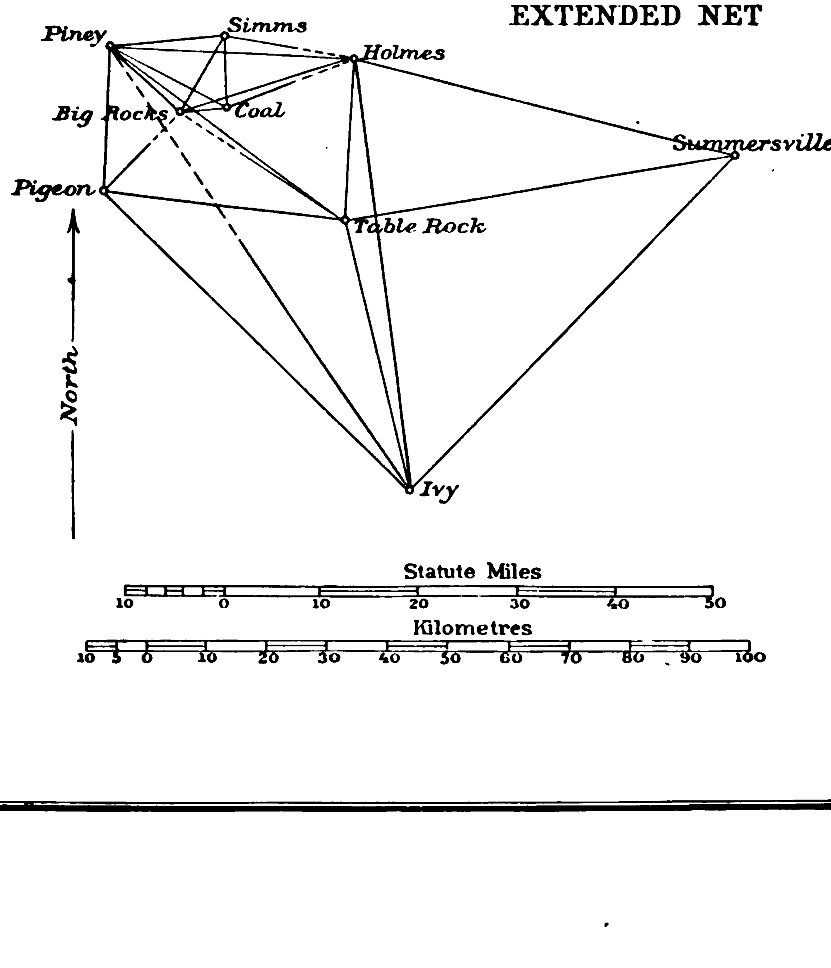
The base was located by Assistant A. T. Mosman, and in the summer of 1891 the terminal stones were set and the profile of the line secured by Subassistant W. B. Fairfield;* the measurement of the base in October, 1892, was in charge of Assistant R. S. Woodward. The base was divided into four sections and between October 1 and 9 the line was cleared of obstacles and the marking and support stakes for the tapes were set, 10

* The connection of the base with the main triangulation was made by the same observer in 1893.

SAINT ALBANS BASE NET, W. VA.
1880 TO 1893



EXTENDED NET



metres apart, and carefully aligned and the slope determined. All measures were made between October 10 and October 14. Four of these were made at night and one during bright sunshine, but the observer excluded the last result from his final combination. Of the four effective measures two were forward and two were backward; they were made with steel tapes Nos. 85 and 88, the same as had been previously employed and standardized at the Holton Base in the preceding year. As there stated, the lengths of the tapes depend on comparative measures with the 5-metre steel bar No. 17 when embedded in melting ice. The dimensions of these tapes are: Length 101·01 metres, cross section 6·34 by 0·47 millimetres. Their weight is 22·3 grammes per metre of length. When not in use, they are rolled up on reels. During measure the tension applied was 25 pounds 6 ounces. The following results were found:

$$\text{Bar } B_{17} = 5m - 18{\cdot}0\mu \text{ at } 0^\circ \text{ C. and}$$

$$\text{Tape } T_{85} = 20\,B_{17} + \overset{\text{mm.}}{3{\cdot}86} + \overset{\text{mm.}}{1{\cdot}094}\,7t \text{ or } T_{85} = 100m + \overset{\text{mm.}}{3{\cdot}50} + \overset{\text{mm.}}{1{\cdot}094}\,7t$$

$$T_{88} = 20\,B_{17} + 6{\cdot}31 + 1{\cdot}091\,4t \qquad T_{88} = 100m + 5{\cdot}95 + 1{\cdot}091\,4t$$

These numbers answer to the standard tension of 25 pounds and 9 ounces* and are for the centigrade temperature t (referred to the hydrogen scale). The fractional part of a tape was obtained either directly from the 20-metre subspaces of the tapes or by means of a 15-metre tape graduated to millimetres. The several positions of the tapes were marked on zinc plates left in position throughout the measures, these marks forming part of the record. The corrections to the thermometer readings during the base measures are as follows:

Tempera-ture.	Thermometers. Green No. 5598.	Green No. 5620.	Green No. 5621.
°	°	°	°
0	—0·10	—0·20	—0·25
5	·12	·15	·20
10	·09	·21	·26
15	·08	·25	·32
20	·08	·27	·34
25	·07	·25	·32
30	·04	·25	·25
35	—0·09	—0·23	—0·28

These thermometers were provided with steel sheaths of thin steel tape slipped over their bulbs, in the hope of securing a close approximation to the actual temperature of the tapes. Two of the thermometers were placed at a distance of 10 metres from the tape ends and the third one was placed at the middle.

* With 3 ounces less than the standard tension the tape shortens 0·14 millimetre.

The results of the several measures of the base sections in terms of the length of B_{17} are as follows:

Section.	Date, 1892.	Time of day. p. m.		Direction of measure.	End points.	No. of tape.	Mean temperature.	Temperature rising or falling.	Length.	Grade correction.
		h. m.	*h. m.*				°C.		*mm.*	*mm.*
I	Oct. 11	7 20 to	8 02	W.	West Base to Stake 10.	88	9·04	f.	$200B_{17}+258·2$	−8.52
	12	9 03	9 44	E.		88	7.62	r.	244·5	
	13	7 06	7 40	W.		85	13·30	f.	252·6	
	13	10 49	11 21	E.		85	9·56	r.	251·5	
	14	2 53	3 16	W.		88	32·11	r., f.	248·1	
II	Oct. 11	8 02	8 44	W.	Stake 10 to Stake 20.	88	5·92	f., r.	$200B_{17}+534·8$	−93·58
	12	9 44	10 25	E.		88	6·39	f., r.	535·5	
	13	7 40	8 12	W.		85	10·38	f., r.	533·0	
	13	11 21	11 53	E.		85	9·05	f., r., f.	536·0	
	14	3 16	3 49	W.		88	30·47	f., r.	536·0	
III	Oct. 11	8 44	9 26	W.	Stake 20 to Stake 30.	88	6·23	r., f., r.	$200B_{17}+527·0$	−7·20
	12	7 40	8 22	E.		88	7·84	r., f.	524·0	
	13	8 12	8 44	W.		85	9·92	f., r., f.	527·8	
	13	9 45	10 17	E.		85	8·75	r., f., r.	528·9	
	14	3 49	4 02	W.		88	30·08	r., f., r.	534·0	
IV	Oct. 11	9 26	10 08	W.	Stake 30 to East Base.	88	4·80	f., r.	$172B_{17}+9\ 325·5$	−3·40
	12	8 22	9 03	E.		88	7·92	f., r.	9 323·0	
	13	8 44	9 16	W.		85	9·24	f., r.	9 321·4	
	13	10 17	10 49	E.		85	8·57	f., r., f.	9 328·6	
	14	4 02	4 26	W.		88	29·80	r., f., r.	9 333·0	

Summary of resulting lengths of each section and by each tape, but omitting the fifth or daylight measure.*

Section.	Length by— Tape No. 88.	Length by— Tape No. 85.	Mean.	Correction for slope.	Resulting length.
	mm.	*mm.*	*mm.*	*mm.*	*m.*
I	$200B_{17}+$ 251·35	+ 252·05	+ 251·70	− 8·52	1 000·239 6
II	200 + 535·15	+ 534·50	+ 534·82	− 93·58	1 000·437 6
III	200 + 525·50	+ 528·35	+ 526·93	− 7·20	1 000·516 1
IV	172 + 9 324·25	+ 9 325·00	+ 9 324·62	− 3·40	869·318 1
Total	$772B_{17}+10\ 636·25$	+10 639·90	+10 638·07	−112·70	3 870·511 4

Length of base* from—

	m.
2 westward measures	3 870·513 5
2 eastward measures	3 870·509 3
Mean	3 870·511 4

Also difference of measure by the two tapes 3·65 millimetres.

* Unreduced to sea level.

The individual results of the 4 night and the 1 day measures are:

1892.			Mean.	Mean.
		m.	mm.	
Oct. 11	N.	3 870·518 9	509·6	
12	N.	·500 4		mm.
13	N.	·508 2	513·3	511·41
13	N.	·518 4		
14	D.	·524 5		
Mean		3 870·514 1		

For the reduction to sea level we have the following data: Average distance of tape below stone at West Base, 2·66 feet; stone at West Base below bench mark at St. Albans, 1·29 feet; result of spirit leveling in November, 1891, by Sub-Assistant Fairfield, from forward and backward measures, bench mark below triangulation station, Big Rocks, 576·05 feet; top of pier at Big Rocks above ground, 3·40 feet; hence tape below ground at Big Rocks, 576·60 feet, or 175·75 metres. The height of this station resulting from measures of zenith distances brought over from the survey of the District of Columbia is 356·23 metres $\pm$ 1·75 metres; adding to this accumulated probable error the uncertainty in the starting level $\pm$ 0·23 metre, we get for the average height of the base 180·48 metres $\pm$ 1·76 metres, with the corresponding reduction to sea level $-$ 0·109 6 metre; the length of the base reduced to sea level is therefore 3 870·401 8 metres. There is still to be applied a small correction to the length of the base, due to thermometric corrections, amounting to* + 0·97 millimetre; hence final length of base is 3 870·402 8 metres.

The probable error of the assigned length of the base may be deduced in different ways; that due to the uncertainty in measure may be made to depend on the discrepancies as shown by the 5 measures of each of the 4 sections and noting the fact that the sum of the squares of the differences for the last, or daylight, measure is not the largest of these values. We find for the probable error of the base measure

$$0{\cdot}674\left(\frac{\Sigma S^2}{n(n-1)}\right)^{\frac{1}{2}} = \pm 2{\cdot}38 \text{ millimetres.}$$

The probable error arising from the uncertainty in the assigned length of a tape, is given by the observer as $\pm$ 0·06 millimetre; hence probable error of the base from this cause is $38{\cdot}7 \times 0{\cdot}06 = \pm 2{\cdot}32$ millimetres. The probable error of the base from uncertainty in the reduction to sea level is $\pm$ 1·10 millimetres; hence total probable error $\sqrt{(2{\cdot}38)^2 + (2{\cdot}32)^2 + (1{\cdot}10)^2} = \pm 3{\cdot}50$ millimetres, or about $\frac{1}{1106000}$ part of the length.

	m.
Resulting length of the St. Albans Base	3 870·402 8
	$\pm$ 3 5
and its logarithm	3·587 756 17
	$\pm$ 39

* See p. 468, Coast and Geodetic Survey Report for 1892, part

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE ST. ALBANS BASE NET, 1880–81, 1883, 1891–92–93.

St. Albans East Base, Kanawha County, West Virginia. January 24 to January 31, 1893. 30-centimetre theodolite, No. 118. W. B. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
60	Rogers	0 00 00·00	+0·37	00·37
61	St. Albans West Base	13 54 31·28	−0·08	31·20
62	Ryan	89 11 54·74	−0·29	54·45

Approximate probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·93.

St. Albans West Base, Kanawha County, West Virginia. February 3 to February 10, 1893. 30-centimetre theodolite, No. 118. W. B. Fairfield, observer.

		° ′ ″	″	″
63	Ryan	0 00 00·00	−0·61	$\overline{59}$·39
64	St. Albans East Base	28 57 00·54	+0·60	01·14
65	Rogers	132 44 39·75	+0·01	39·76

Approximate probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·73.

Big Rocks, Kanawha County, West Virginia. November 30 to December 9, 1891. 30-centimetre theodolite, No. 118. W. B. Fairfield, observer.

		° ′ ″	″	″
30	Piney	0 00 00·00	−0·02	$\overline{59}$·98
31	Simms	79 17 34·08	+0·86	34·94
32	Rogers	109 27 01·41	−0·02	01·39
33	Ryan	112 06 27·25	+0·20	27·45
34	Holmes	120 01 36·30	−0·59	35·71
35	Coal	130 04 18·04	−0·43	17·61
	Table Rock	170 12		30·58
	Pigeon	270 35		38·35

Approximate probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·59.

Piney, Cabell County, West Virginia. August 21 to September 4, 1883. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers. December 16 to December 21, 1891. 30-centimetre theodolite, No. 118. W. B. Fairfield, observer.

		° ′ ″	″	″
29	Pigeon	0 00 00·00	−0·17	$\overline{59}$·83
	Davis	66 33 51·05		
	Gebhardt	117 16 06·01		
24	Simms	265 09 53·84	−0·28	53·56
25	Holmes	270 36 07·62	+0·21	07·83
26	Coal	293 29 60·19	−0·39	59·80
27	Table Rock	304 16 56·84	+0·45	57·29
28	Big Rocks	310 51 38·03	+0·18	38·21
	Ivy	323 43		20·68

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·65.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE ST. ALBANS BASE NET, 1880–81, 1883, 1891–92–93—continued.

Simms, Putnam County, West Virginia. January 16 to February 10, 1892. 30-centimetre theodolite, No. 118. W. B. Fairfield, observer. Telescope above ground about 17 metres.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″
37	Ryan	0	00	00·00	+0·85	00·85
38	Coal	25	32	09·02	+0·20	09·22
39	Rogers	34	34	53·71	+0·09	53·80
40	Big Rocks	64	55	28·25	−0·41	27·84
41	Piney	119	56	09·04	−0·26	08·78
36	Holmes	310	06	23·22	−0·48	22·74

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''\cdot 59$.

Ryan, Kanawha County, West Virginia. November 29 to December 22, 1892. 30-centimetre theodolite, No. 118. W. B. Fairfield, observer.

		°	′	″	″	″
59	Simms	0	00	00·00	−0·64	$\overline{59}$·36
54	St. Albans East Base	216	09	15·81	+0·23	16·04
55	Coal	245	30	30·40	+0·07	30·47
56	Big Rocks	277	44	18·60	+0·03	18·63
57	Rogers	282	20	26·53	+0·39	26·92
58	St. Albans West Base	291	54	51·14	−0·08	51·06

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''\cdot 70$.

Rogers, Kanawha County, West Virginia. February 23 to February 28, 1893. 30-centimetre theodolite, No. 118. W. B. Fairfield, observer.

		°	′	″	″	″
48	Simms	0	00	00·00	−0·20	$\overline{59}$·80
49	St. Albans West Base	30	04	39·08	−0·10	38·98
50	Ryan	67	45	34·27	+0·22	34·49
51	St. Albans East Base	92	22	30·48	−0·93	29·55
52	Coal	147	02	33·78	+1·51	35·29
53	Big Rocks	240	30	00·64	−0·50	00·14

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 1''\cdot 30$.

Coal, Kanawha County, West Virginia. March 14 to March 29, 1893. 30-centimetre theodolite, No. 118. W. B. Fairfield, observer.

		°	′	″	″	″
42	Big Rocks	0	00	00·00	+0·99	00·99
43	Piney	32	34	04·93	+0·28	05·21
44	Rogers	65	55	21·51	−1·53	19·98
45	Simms	89	49	60·49	−0·56	59·93
46	Ryan	129	48	22·62	+0·15	22·77
47	Holmes	165	55	04·33	+0·67	05·00

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''\cdot 66$.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE ST. ALBANS BASE NET, 1880–81, 1883, 1891–92–93—continued.

Summersville, Nicholas County, West Virginia. November 9 to December 5, 1880. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″
	Beach	0	00	00·00		
1	Ivy	95	56	58·36	−0·27	58·09
2	Table Rock	132	04	23·34	+0·29	23·63
3	Holmes	155	27	36·85	−0·02	36·83
	Briery	339	07	44·10		

Probable error of a single observation of a direction ($D.$ and $R.$) = ± 0″·86.

Ivy, Raleigh County, West Virginia. June 14 to June 21, 1881. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	″	″
6	Table Rock	0	00	00·00	−0·05	59·95
7	Holmes	6	33	23·49	+0·15	23·64
8	Summersville	58	22	03·66	−0·09	03·57
	Beech	78	34	19·05		
	Keeney	104	44	04·82		
4	Pigeon	327	57	11·54	+0·09	11·63
5	Piney	339	33	29·00	−0·10	28·90

Probable error of a single observation of a direction ($D.$ and $R.$) = ± 0″·81.

Table Rock, Kanawha County, West Virginia. July 19 to August 15, 1881. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	″	″
12	Holmes	0	00	00·00	−0·03	59·97
	Creed	7	11	29·86		
13	Summersville	76	37	16·12	+0·37	16·49
14	Ivy	162	07	55·05	−0·06	54·99
9	Pigeon	272	29	39·43	−0·48	38·95
10	Big Rocks	299	02	15·27	+0·17	15·44
11	Piney	302	15	04·12	+0·03	04·15

Probable error of a single observation of a direction ($D.$ and $R.$) = ± 1″·09.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE ST. ALBANS BASE NET, 1880–81, 1883, 1891–92–93—Continued.

Holmes, Kanawha County, West Virginia. August 26 to September 27, 1881. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
17	Table Rock	0 00 00·00	−0·30	59·70
	Martin	3 33 12·21		
	Elk	13 47 20·76		
	Coal	64 49		08·03
18	Big Rocks	68 51 22·56	−0·33	22·23
19	Piney	88 34 16·67	+0·50	17·17
	Simms	93 18		17·05
15	Summersville	280 00 25·50	−0·42	25·08
	Creed	307 49 07·41		
16	Ivy	348 41 16·93	+0·55	17·48

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 1''.48$.

Pigeon, Lincoln County, West Virginia. July 21 to August 5, 1883. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
20	Piney	0 00 00·00	−0·12	59·88
21	Big Rocks	41 27 17·14	+0·20	17·34
22	Table Rock	94 31 34·23	+0·32	34·55
23	Ivy	132 07 07·02	−0·40	06·62
	Davis	296 48 34·59		
	Gebhardt	332 13 32·79		

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''.72$

FIGURE ADJUSTMENT.

*Observation equations.**

No.	
1	$0 = -0.09 + (14) - (13) + (2) - (1) + (8) - (6)$
2	$0 = -0.98 + (16) - (15) + (3) - (1) + (8) - (7)$
3	$0 = -0.22 + (17) - (15) + (3) - (2) + (13) - (12)$
4	$0 = -0.98 + (27) - (25) + (19) - (17) + (12) - (11)$
5	$0 = +1.29 + (23) - (22) + (9) - (14) + (6) - (4)$
6	$0 = -0.33 + (22) - (20) + (29) - (27) + (11) - (9)$
7	$0 = -0.24 + (34) - (30) + (28) - (25) + (19) - (18)$
8	$0 = -1.49 + (41) - (40) + (31) - (30) + (28) - (24)$
9	$0 = +0.54 + (43) - (42) + (35) - (30) + (28) - (26)$
10	$0 = +1.41 + (45) - (43) + (26) - (24) + (41) - (38)$
11	$0 = -2.58 + (52) - (48) + (39) - (38) + (45) - (44)$
12	$0 = +1.52 + (56) - (55) + (46) - (42) + (35) - (33)$

*Number of conditions in the net 30; of these 18 relate to sums of angles and 12 to ratio of sides. The side equations are established with 7 places of decimals in the logs, and differences for 1″ are cut off at the sixth place, except equations 24 and 25, which are carried one place farther.

FIGURE ADJUSTMENT—continued.

Observation equations—Continued.

No.	
13	$0 = +0.66 + (59) - (55) + (46) - (45) + (38) - (37)$
14	$0 = +1.36 + (59) - (57) + (50) - (48) + (39) - (37)$
15	$0 = +0.13 + (53) - (50) + (57) - (56) + (33) - (32)$
16	$0 = +1.65 + (62) - (60) + (51) - (50) + (57) - (54)$
17	$0 = -0.46 + (65) - (63) + (58) - (57) + (50) - (49)$
18	$0 = -0.69 + (62) - (61) + (64) - (63) + (58) - (54)$
19	$0 = -15.7 - 2.88(1) + 7.75(2) - 4.87(3) - 17.02(6) + 18.32(7) - 1.30(8) - 0.37(15) + 10.52(16) - 10.15(17)$
20	$0 = -1.3 - 3.36(4) + 11.61(5) - 8.25(6) - 5.96(11) + 5.96(14) + 0.17(20) + 2.57(22) - 2.74(23) + 1.43(27) - 1.43(29)$
21	$0 = -6.3 - 2.88(1) + 7.75(2) - 4.87(3) - 3.36(4) + 4.66(6) - 1.30(8) - 0.37(15) + 0.42(17) - 0.05(19) + 0.17(20) + 2.57(22) - 2.74(23) - 3.16(25) + 4.59(27) - 1.43(29)$
22	$0 = -4.3 - 4.22(9) + 41.72(10) - 37.50(11) - 2.38(20) + 3.96(21) - 1.58(22) - 18.25(27) + 20.07(28) - 1.82(29)$
23	$0 = +0.8 - 4.22(9) + 5.39(10) - 1.17(12) - 0.81(17) + 6.68(18) - 5.87(19) - 2.38(20) + 3.96(21) - 1.58(22) - 2.48(25) + 4.30(28) - 1.82(29)$
24	$0 = +29.8 - 39.05(24) + 106.40(26) - 67.35(28) + 17.71(30) + 17.18(31) - 34.89(35) - 27.26(38) + 25.64(40) + 1.62(41)$
25	$0 = -112.1 - 39.05(24) + 97.70(25) - 58.65(26) - 44.27(36) + 42.65(38) + 1.62(41) + 47.85(43) - 38.80(45) - 9.05(47)$
26	$0 = +4.5 - 9.77(25) + 16.51(26) - 6.74(28) + 1.77(30) + 41.71(34) - 43.48(35) + 29.83(42) - 4.78(43) - 25.05(47)$
27	$0 = +7.5 - 3.62(31) + 9.21(32) - 5.59(35) - 13.23(38) + 16.82(39) - 3.59(40) - 0.94(42) + 5.69(44) - 4.75(45)$
28	$0 = +3.9 - 3.62(31) + 48.98(32) - 45.36(33) - 3.06(37) + 6.65(39) - 3.59(40) - 26.16(56) + 26.62(57) - 0.46(59)$
29	$0 = +4.2 - 3.62(31) + 9.21(32) - 5.59(35) - 3.06(37) + 6.65(39) - 3.59(40) - 0.94(42) + 1.97(44) - 1.03(46) - 2.81(55) + 3.27(57) - 0.46(59)$
30	$0 = -3.9 - 1.62(49) + 2.73(50) - 1.11(51) - 0.53(54) + 12.48(57) - 11.95(58) - 8.50(60) + 9.05(61) - 0.55(62)$

Correlate equations.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
(1)	−1	−1											
(2)	+1		−1										
(3)		+1	+1										
(4)					−1								
(5)	....	....	....	....	....	....	....	....	....	....	....	....	....
(6)	−1				+1								
(7)		−1											
(8)	+1	+1											
(9)					+1	−1							

FIGURE ADJUSTMENT—continued.

Correlate equations—Continued.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
(10)	....	....	....	....	....	....	....	....	....	....	....	....	....
(11)				−1		+1							
(12)			−1	+1									
(13)	−1		+1										
(14)	+1				−1								
(15)	....	−1	−1	....	....	....	....	....	....	....	....	....	....
(16)		+1											
(17)			+1	−1									
(18)							−1						
(19)				+1			+1						
(20)	....	....	....	....	....	−1	....	....	....	....	....	....	....
(21)													
(22)					−1	+1							
(23)					+1								
(24)								−1		−1			
(25)	....	....	....	−1	....	....	−1	....	....	....	....	....	....
(26)									−1	+1			
(27)				+1		−1							
(28)							+1	+1	+1				
(29)						+1							
(30)	....	....	....	....	....	....	−1	−1	−1	....	....	....	....
(31)								+1					
(32)													
(33)												−1	
(34)							+1						
(35)	....	....	....	....	....	....	....	....	+1	....	....	+1	....
(36)													
(37)													−1
(38)										−1	−1		+1
(39)											+1		
(40)	....	....	....	....	....	....	....	−1	....	....	....	....	....
(41)								+1		+1			
(42)									−1			−1	
(43)									+1	−1			
(44)											−1		
(45)	....	....	....	....	....	....	....	....	....	+1	+1	....	−1
(46)												+1	+1
(47)													
(48)											−1		
(49)													
(50)	....	....	....	....	....	....	....	....	....	....	....	....	....

FIGURE ADJUSTMENT—continued.

Correlate equations—Continued.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
(51)													
(52)											+1		
(53)													
(54)													
(55)	....	....	....	....	....	....	....	....	....	....	....	−1	−1
(56)												+1	
(57)													
(58)													
(59)													+1

Correlate equations - Continued.

Corrections.	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}
(1)						−2·88		−2·88	
(2)						+7·75		+7·75	
(3)						−4·87		−4·87	
(4)							−3·36	−3·36	
(5)	....	....	....	....	....	....	+11·61	....	....
(6)						−17·02	−8·25	−4·66	
(7)						+18·32			
(8)						−1·30		−1·30	
(9)									−4·22
(10)	....	....	....	....	....	....	....	....	+41·72
(11)							−5·96		−37·50
(12)									
(13)									
(14)							+5·96		
(15)	....	....	....	....	....	−0·37	....	−0·37	....
(16)						+10·52			
(17)						−10·15		+0·42	
(18)									
(19)								−0·05	
(20)	....	....	....	....	....	....	+0·17	+0·17	−2·38
(21)									+3·96
(22)							+2·57	+2·57	−1·58
(23)							−2·74	−2·74	
(24)									
(25)	....	....	....	....	....	....	....	−3·16	....
(26)									
(27)							+1·43	+4·59	−18·25
(28)									+20·07

FIGURE ADJUSTMENT—continued.

Correlate equations—Continued.

Corrections.	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}
(29)							−1·43	−1·43	−1·82
(30)	....	....	....	....	....	....	....	....	....
(31)									
(32)		−1							
(33)		+1							
(34)									
(35)	....	....	....	....	....	....	....	....	....
(36)									
(37)	−1								
(38)									
(39)	+1								
(40)	....	....	....	....	....	....	....	....	....
(41)									
(42)									
(43)									
(44)									
(45)	....	....	....	....	....	....	....	....	....
(46)									
(47)									
(48)	−1								
(49)				−1					
(50)	+1	−1	−1	+1	....	....	....	....	....
(51)			+1						
(52)									
(53)		+1							
(54)			−1		−1				
(55)	....	....	....	....	....	....	....	....	....
(56)		−1							
(57)	−1	+1	−1	−1					
(58)				+1	+1				
(59)	+1								
(60)	....	....	−1	....	....	....	....	....	....
(61)					−1				
(62)			+1		+1				
(63)				−1	−1				
(64)					+1				
(65)	....	....	....	+1	....	....	....	....	....

FIGURE ADJUSTMENT—continued.

Correlate equations—Continued.

Corrections.	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}
(1)								
(2)								
(3)								
(4)								
(5)	....	....	....	....	....	....	....	....
(6)								
(7)								
(8)								
(9)	−4·22							
(10)	·5·39	....	....	...	....	....	....	....
(11)								
(12)	−1·17							
(13)								
(14)								
(15)	....	....	....	....	...	....	....	....
(16)								
(17)	−0·81							
(18)	+6·68							
(19)	−5·87							
(20)	−2·38	...	...	....	....	....	....	....
(21)	+3·96							
(22)	−1·58							
(23)								
(24)		−39·05	−39·05					
(25)	−2·48	....	+97·70	−9·77	....	....	....	....
(26)		·106·40	−58·65	·16·51				
(27)								
(28)	+4·30	−67·35		−6·74				
(29)	−1·82							
(30)	....	+17·71	....	+1·77	....	...	....	....
(31)		+17·18			−3·62	−3·62	−3·62	
(32)					+9·21	+48·98	+9·21	
(33)						−45·36		
(34)				+41·71				
(35)	....	−34·89	....	−43·48	−5·59	....	−5·59	....
(36)			−44·27					
(37)						−3·06	−3·06	
(38)		−27·26	+42·65		−13·23			
(39)					+16·82	+6·65	+6·65	
(40)	....	+25·64	....	....	−3·59	−3·59	−3·59	....
(41)		+1·62	+1·62					

FIGURE ADJUSTMENT—continued.

Correlate equations—Completed.

Corrections.	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}
(42)				+29·83	−0·94		−0·94	
(43)			+47·85	−4·78				
(44)					+5·69		+1·97	
(45)	....	....	−38·80	....	−4·75	....	....	....
(46)							−1·03	
(47)			−9·05	−25·05				
(48)								
(49)								−1·62
(50)	....	....	....	....	....	....	....	+2·73
(51)								−1·11
(52)								
(53)								
(54)								−0·53
(55)	....	....	....	....	....	....	−2·81	....
(56)						−26·16		
(57)						+26·62	+3·27	+12·48
(58)								−11·95
(59)						−0·46	−0·46	
(60)	....	....	....	....	....	....	....	−8·50
(61)								+9·05
(62)								−0·55

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
0 = −0·09	+6	+2	−2		−2								
−0·98		+6	+2										
−0·22			+6	−2									
−0·98				+6		−2	+2						
+1·29	...	...	...	...	+6	−2	...	...	...	...	...	...	...
−0·33						+6							
−0·24							+6	+2	+2				
−1·49								+6	+2	+2			
+0·54									+6	−2		+2	
+1·41	...	...	...	...	...	..	...	...	...	+6	+2	...	−2
−2·58											+6		−2
+1·52												+6	+2
+0·66													+6

FIGURE ADJUSTMENT—continued.

Normal equations—Continued.

	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}
− 0·09						+26·35	+14·21	+ 4·67	
− 0·98						−10·72		− 2·92	
− 0·22						−22·40		−11·83	
− 0·98						+10·15	+ 7·39	+ 7·28	+19·25
+ 1·29	...	...	...	...	...	−17·02	−16·16	+ 2·71	− 2·64
− 0·33							− 6·42	− 3·62	−16·05
− 0·24								+ 3·11	+20·07
− 1·49									+20·07
+ 0·54									+20·07
+ 1·41	...	...	...	...	...	......	......	......	......
− 2·58	+2								
+ 1·52		−2							
+ 0·66	+2								
0 = + 1·36	+6	−2	−2	+2					
+ 0·13	...	+6	+2	−2	...	......	......	......	......
+ 1·65			+6	−2	+2				
− 0·46				+6	+2				
− 0·69					+6				
−15·7						+932·90	+140·41	+ 10·32	
− 1·3	...	...	...	..	...	......	+303·42	− 4·40	+ 195·54
− 6·3								+174·33	− 85·63
− 4·3									+3 927·64

Normal equations—Continued

	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}
− 0·22	+0·36							
− 0·98	−3·75		− 97·70	+ 9·77				
+ 1·29	−2·64	......	......	......	......	......	......	......
− 0·33	+3·20							
− 0·24	−5·77	− 85·06	− 97·70	+ 42·97				
− 1·49	+4·30	− 52·85	+ 40·67	− 8·51	− 0·03	− 0·03	−0·03	
+ 0·54	+4·30	−226·35	+106·50	−103·11	− 4·65		−4·65	
+ 1·41	......	+174·33	−147·28	+ 21·29	+ 8·48	......	......	......
− 2·58		+ 27·26	− 81·45		+19·61	+ 6·65	+4·68	
+ 1·52		− 34·89		− 73·31	− 4·65	+19·20	−2·87	
+ 0·66		− 27·26	+ 81·45		− 8·48	+ 2·60	+4·38	
+ 1·36					+16·82	−17·37	+5·98	− 9·75
+ 0·13	......	......	......	......	− 9·21	−41·56	−5·94	+ 9·75
+ 1·65						+26·62	+3·27	+17·12
− 0·46						−26·62	−3·27	−20·08
− 0·69								−21·02

FIGURE ADJUSTMENT—completed.

Normal equations—Completed.

	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}
− 15·7	+8·22							
− 1·3	−1·86	......	......	......	......	......	......	......
− 6·3	+5·93		−308·73	+ 30·87				
− 4·3	+356·13	−1 351·71		−135·17				
0 = + 0·8	+179·76	− 289·60	−242·30	− 4·73				
+ 29·8		+20 611·12	− 5 875·48	+3 758·65	+401·45	−154·24	+ 40·80	
−112·1	......	......	+22 168·45	−1 925·10	−379·96	......	......	......
+ 4·5				+5 586·94	+215·01		+215·01	
+ 7·5					+655·83	+588·95	+266·01	
+ 3·9						+5 929·33	+617·94	+332·22
+ 4·2							+220·28	+ 40·81
− 3·9	......	......	......	......	......	......	......	+464·60

Resulting values of correlates and of corrections to angular directions:

$C_1 = -0·272$	$C_9 = -1·312$	$C_{17} = -0·005$	$C_{25} = -0·010\ 8$
$C_2 = +0·294$	$C_{10} = -0·928$	$C_{18} = +0·605$	$C_{26} = -0·030\ 8$
$C_3 = +0·098$	$C_{11} = +1·512$	$C_{19} = +0·024\ 1$	$C_{27} = +0·017\ 2$
$C_4 = +0·130$	$C_{12} = -0·556$	$C_{20} = -0·008\ 24$	$C_{28} = -0·003\ 18$
$C_5 = -0·264$	$C_{13} = +0·642$	$C_{21} = +0·061\ 0$	$C_{29} = -0·057\ 0$
$C_6 = +0·002$	$C_{14} = -1·307$	$C_{22} = -0·002\ 91$	$C_{30} = +0·058\ 2$
$C_7 = +0·694$	$C_{15} = -0·499$	$C_{23} = -0·054\ 2$	
$C_8 = +0·648$	$C_{16} = -0·865$	$C_{24} = -0·003\ 45$	

″	″	″	″
(1) = −0·267	(18) = −0·332	(35) = −0·426	(52) = +1·512
(2) = +0·290	(19) = +0·503	(36) = −0·478	(53) = −0·499
(3) = −0·022	(20) = −0·115	(37) = +0·849	(54) = +0·229
(4) = +0·087	(21) = +0·203	(38) = +0·197	(55) = +0·074
(5) = −0·096	(22) = +0·316	(39) = +0·094	(56) = +0·026
(6) = −0·050	(23) = −0·403	(40) = −0·406	(57) = +0·393
(7) = +0·148	(24) = −0·277	(41) = −0·257	(58) = −0·085
(8) = −0·088	(25) = +0·205	(42) = +0·987	(59) = −0·638
(9) = −0·483	(26) = −0·391	(43) = +0·280	(60) = +0·370
(10) = +0·171	(27) = +0·449	(44) = −1·526	(61) = −0·079
(11) = +0·030	(28) = +0·181	(45) = −0·559	(62) = −0·292
(12) = −0·031	(29) = −0·167	(46) = +0·145	(63) = −0·610
(13) = +0·370	(30) = −0·024	(47) = +0·674	(64) = +0·605
(14) = −0·057	(31) = +0·863	(48) = −0·205	(65) = +0·005
(15) = −0·424	(32) = −0·024	(49) = −0·099	
(16) = +0·548	(33) = +0·201	(50) = +0·221	
(17) = −0·295	(34) = −0·591	(51) = −0·930	

Σ of + corrections 11·226
Σ of − corrections 11·226

Check: $[pvv] = +14·199$
$-[wC] = +14·207$

Mean error of an observed *direction* $m_1 = \sqrt{\frac{[pvv]}{n}} = \pm 0''·69$ where n = number of conditional equations; mean error of an *angle* $m_< = m_1\sqrt{2} = \pm 0''·98$; also probable error of the same $= \pm 0''·66$.

TRIANGLES OF THE ST. ALBANS BASE NET, WEST VIRGINIA, 1880–1893.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
1	Ryan	75	45	35·33	−0·31	35·02	0·00	3·587 756 2	3 870·403
	St. Albans East Base	75	17	23·46	−0·21	23·25	0·01	3·586 836 6	3 862·22
	St. Albans West Base	28	57	00·54	+1·21	01·75	0·01	3·286 203 6	1 932·87
				59·33			0·02		
2	Rogers	62	17	51·40	−0·83	50·57	0·00	3·587 756 2	3 870·403
	St. Albans West Base	103	47	39·21	−0·60	38·61	0·01	3·627 920 6	4 245·42
	St. Albans East Base	13	54	31·28	−0·45	30·83	0·00	3·021 516 3	1 050·79
				01·89			0·01		
3	Ryan	66	11	10·72	+0·16	10·88	0·01	3·627 920 6	4 245·42
	St. Albans East Base	89	11	54·74	−0·66	54·08	0·00	3·666 521 8	4 640·04
	Rogers	24	36	56·21	−1·15	55·06	0·01	3·286 203 7	1 932·87
				01·67			0·02		
4	Rogers	37	40	55·19	+0·32	55·51	0·00	3·586 836 6	3 862·22
	St. Albans West Base	132	44	39·75	+0·62	40·37	0·01	3·666 521 8	4 640·04
	Ryan	9	34	24·61	−0·48	24·13	0·00	3·021 516 2	1 050·79
				59·55			0·01		
5	Coal	63	53	01·11	+1·67	02·78	0·01	3·666 521 8	4 640·04
	Rogers	79	16	59·51	+1·30	60·81	0·02	3·705 649 9	5 077·50
	Ryan	36	49	56·13	+0·32	56·45	0·01	3·491 062 6	3 097·87
				56·75			0·04		
6	Simms	34	34	53·71	−0·76	52·95	0·03	3·666 521 8	4 640·04
	Ryan	77	39	33·47	−1·03	32·44	0·03	3·902 344 7	7 986·28
	Rogers	67	45	34·27	+0·43	34·70	0·03	3·878 923 1	7 566·99
				01·45			0·09		
7	Simms	9	02	44·69	−0·10	44·59	0·01	3·491 062 6	3 097·87
	Coal	23	54	38·98	+0·97	39·95	0·01	3·902 344 4	7 986·28
	Rogers	147	02	33·78	+1·71	35·49	0·01	4·030 152 1	10 718·95
				57·45			0·03		
8	Simms	25	32	09·02	−0·65	08·37	0·03	3·705 649 9	5 077·50
	Ryan	114	29	29·60	−0·71	28·89	0·03	4·030 152 3	10 718·95
	Coal	39	58	22·13	+0·70	22·83	0·03	3·878 923 0	7 566·99
				00·75			0·09		
9	Big Rocks	17	57	50·79	0·63	50·16	0·03	3·705 649 9	5 077·50
	Ryan	32	13	48·20	−0·05	48·15	0·03	3·943 497 8	8 780·07
	Coal	129	48	22·62	−0·84	21·78	0·03	4·101 993 4	12 647·17
				01·61			0·09		
10	Big Rocks	32	48	53·17	−0·66	52·51	0·08	3·878 923 1	7 566·99
	Simms	64	55	28·25	−1·26	26·99	0·08	4·101 993 7	12 647·18
	Ryan	82	15	41·40	−0·66	40·74	0·08	4·141 013 0	13 836·08
				02·82			0·24		

TRIANGLES OF THE ST. ALBANS BASE NET, WEST VIRGINIA, 1880–1893—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
11	Big Rocks	50	46	43·96	−1·29	42·67	0·08	4·030 152 2	10 718·95
	Simms	39	23	19·23	−0·60	18·63	0·08	3·943 497 7	8 780·06
	Coal	89	49	60·49	−1·55	58·94	0·08	4·141 012 8	13 836·07
				03·68			0·24		
12	Big Rocks	30	09	27·33	−0·89	26·44	0·05	3·902 344 6	7 986·28
	Simms	30	20	34·54	−0·50	34·04	0·05	3·904 754 9	8 030·73
	Rogers	119	29	59·36	+0·30	59·66	0·04	4·141 012 9	13 836·07
				01·23			0·14		
13	Big Rocks	20	37	16·63	−0·41	16·22	0·02	3·491 062 6	3 097·87
	Rogers	93	27	26·86	−2·01	24·85	0·02	3·943 497 8	8 780·07
	Coal	65	55	21·51	−2·52	18·99	0·02	3·904 754 9	8 030·73
				05·00			0·06		
14	Big Rocks	2	39	25·84	+0·22	26·06	0·00	3·666 521 8	4 640·04
	Rogers	172	44	26·37	−0·72	25·65	0·01	4·101 993 7	12 647·18
	Ryan	4	36	07·93	+0·37	08·30	0·00	3·904 755 3	8 030·74
				00·14			0·01		
15	Piney	28	20	06·35	−0·11	06·24	0·17	4·030 152 2	10 718·95
	Simms	94	23	60·02	−0·46	59·56	0·18	4·352 518 6	22 517·42
	Coal	57	15	55·56	−0·84	54·72	0·17	4·278 690 4	18 997·24
				01·93			0·52		
16	Piney	45	41	44·19	+0·46	44·65	0·18	4·141 012 9	13 836·07
	Simms	55	00	40·79	+0·15	40·94	0·18	4·199 742 8	15 839·55
	Big Rocks	79	17	34·08	+0·88	34·96	0·19	4·278 690 6	18 997·24
				59·06			0·55		
17	Piney	17	21	37·84	+0·57	38·41	0·09	3·943 497 8	8 780·07
	Coal	32	34	04·93	−0·71	04·22	0·09	4·199 742 7	15 839·54
	Big Rocks	130	04	18·04	−0·40	17·64	0·09	4·352 518 8	22 517·43
				00·81			0·27		
18	Holmes	19	42	54·11	+0·83	54·94	0·35	4·199 742 8	15 839·55
	Big Rocks	120	01	36·30	−0·57	35·73	0·36	4·609 083 9	40 652·19
	Piney	40	15	30·41	−0·02	30·39	0·35	4·482 059 9	30 343·10
				00.82			1·06		
19	Holmes	28	29	.....		09·02	0·19	4·030 152 2	10 718·95
	Coal	76	05	03·84	+1·23	05·07	0·19	4·338 751 4	21 814·81
	Simms	75	25	45·80	+0·68	46·48	0·19	4·337 490 9	21 751·59
							0·57		

TRIANGLES OF THE ST. ALBANS BASE NET, WEST VIRGINIA, 1880–1893—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
20	Holmes	4	02	.....		14·20	0·04	3·943 497 8	8 780·07
	Coal	165	55	04·33	−0·31	04·02	0·04	4·482 059 8	30 343·09
	Big Rocks	10	02	41·74	+0·16	41·90	0·04	4·337 491 0	21 751·59
							0·12		
21	Holmes	4	43	.....		59·89	0·06	4·278 690 5	18 997·24
	Piney	5	26	13·78	+0·48	14·26	0·06	4·338 751 2	21 814·80
	Simms	169	49	45·82	+0·22	46·04	0·07	4·609 083 6	40 652·16
							0·19		
22	Table Rock	57	44	55·88	−0·06	55·82	0·92	4·609 083 9	40 652·19
	Piney	33	40	49·22	+0·24	49·46	0·92	4·425 805 7	26 656·66
	Holmes	88	34	16·67	+0·80	17·47	0·91	4·681 725 0	48 053·50
				01·77			2·75		
23	Pigeon	94	31	34·23	+0·43	34·66	0·81	4·681 725 0	48 053·50
	Piney	55	43	03·16	−0·61	02·55	0·80	4·600 201 9	39 829·23
	Table Rock	29	45	24·69	+0·51	25·20	0·80	4·378 842 6	23 924·49
				02·08			2·41		
24	Big Rocks	89	24	.....		21·65	0·25	4·378 842 6	23 924·49
	Pigeon	41	27	17·14	+0·32	17·46	0·24	4·199 742 9	15 839·55
	Piney	49	08	21·97	−0·35	21·62	0·24	4·257 561 3	18 095·11
							0·73		
25	Big Rocks	100	23	....		07·77	0·48	4·600 201 9	39 829·23
	Table Rock	26	32	35·84	+0·65	36·49	0·49	4·257 561 2	18 095·11
	Pigeon	53	04	17·09	+0·11	17·20	0·49	4·510 131 0	32 369·13
							1·46		
26	Big Rocks	50	10	....		54·87	0·64	4·425 805 7	26 656·66
	Holmes	68	51	22·56	−0·04	22·52	0·64	4·510 131 0	32 369·13
	Table Rock	60	57	44·73	−0·20	44·53	0·64	4·482 059 9	30 343·10
							1·92		
27	Big Rocks	170	12	....		30·59	0·08	4·681 725 0	48 053·50
	Piney	6	34	41·19	−0·27	40·92	0·07	4·510 131 0	32 369·13
	Table Rock	3	12	48·85	−0·14	48·71	0·07	4·199 742 8	15 839·55
							0·22		
28	Piney	22	53	52·57	−0·60	51·97	0·30	4·337 490 9	21 751·59
	Holmes	23	45	....		09·14	0·30	4·352 518 8	22 517·43
	Coal	133	20	59·40	+0·39	59·79	0·30	4·609 083 8	40 652·18
							0·90		

TRIANGLES OF THE ST. ALBANS BASE NET, WEST VIRGINIA, 1880–1893—Completed.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log s.	Distances in metres.
		°	′	″	″	″	″		
29	Holmes	24	26	....		54·83	0·23	4·141 012 9	13 836·07
	Big Rocks	40	44	02·22	−1·45	00·77	0·23	4·338 751 5	21 814·81
	Simms	114	49	05·03	+0·07	05·10	0·24	4·482 059 8	30 343·09
							0·70		
30	Ivy	32	02	48·46	−0·14	48·32	1·45	4·600 201 9	39 829·23
	Pigeon	37	35	32·79	−0·72	32·07	1·45	4·660 783 2	45 791·33
	Table Rock	110	21	44·38	−0·43	43·95	1·44	4·847 408 2	70 373·34
				05·63			4·34		
31	Ivy	20	26	31·00	+0·05	31·05	1·19	4·681 725 0	48 053·50
	Piney	19	26	....		23·37	1·19	4·660 783 0	45 791·31
	Table Rock	140	07	09·07	+0·09	09·16	1·20	4·945 576 3	88 221·88
							3·58		
32	Ivy	11	36	17·46	−0·18	17·28	1·06	4·378 842 6	23 924·49
	Pigeon	132	07	07·02	−0·29	06·73	1·05	4·945 576 7	88 221·96
	Piney	36	16	....		39·16	1·06	4·847 408 4	70 373·38
							3·17		
33	Ivy	26	59	54·49	+0·24	54·73	2·43	4·609 083 9	40 652·19
	Piney	53	07	....		12·85	2·43	4·855 099 1	71 630·68
	Holmes	99	52	59·74	−0·04	59·70	2·42	4·945 576 5	88 221·92
							7·28		
34	Ivy	6	33	23·49	+0·20	23·69	0·32	4·425 805 7	26 656·66
	Table Rock	162	07	55·05	−0·02	55·03	0·31	4·855 099 1	71 630·68
	Holmes	11	18	43·07	−0·84	42·23	0·32	4·660 783 2	45 791·33
				01·61			0·95		
35	Summersville	36	07	24·98	+0·56	25·54	2·55	4·660 783 2	45 791·33
	Ivy	58	22	03·66	−0·04	03·62	2·55	4·820 429 8	66 134·76
	Table Rock	85	30	38·93	−0·43	38·50	2·56	4·888 948 7	77 437·04
				07·57			7·66		
36	Summersville	23	23	13·51	−0·31	13·20	1·45	4·425 805 7	26 656·66
	Table Rock	76	37	16·12	+0·40	16·52	1·45	4·815 138 7	65 333·92
	Holmes	79	59	34·50	+0·13	34·63	1·45	4·820 429 8	66 134·76
				04·13			4·35		
37	Summersville	59	30	38·49	+0·25	38·74	3·69	4·855 099 1	71 630·68
	Ivy	51	48	40·17	−0·24	39·93	3·69	4·815 138 7	65 333·92
	Holmes	68	40	51·43	+0·97	52·40	3·69	4·888 948 6	77 437·02
				10·09			11·07		

PROBABLE ERRORS.

Determination of the probable errors of the length of the sides common to the net and to the adjacent chains of triangulation.

For the side Summersville to Ivy, as adjusted, we make use of the expression—

$$\frac{\text{Summersville to Ivy}}{\text{St. Albans Base}} = \frac{\sin(16-15)\sin(5-7+16-19)\sin(34-30)\sin(43-42)\sin(53-52)}{\sin(3-1)\sin(7-5)\sin(19-18)\sin(28-26)\sin(35-32)\sin(46-44)}\,\frac{\sin(57-55)\sin(62-60)\sin(64-63)}{\sin(51-50)\sin(58-54)}$$

hence the function—

$F = \log\sin(16-15) + \log\sin(5-7+16-19) + \log\sin(34-30) + \log\sin(43-42) + \log\sin(53-52) + \log\sin(57-55) + \log\sin(62-60) + \log\sin(64-63) - \log\sin(3-1) - \log\sin(7-5) - \log\sin(19-18) - \log\sin(28-26) - \log\sin(35-32) - \log\sin(46-44) - \log\sin(51-50) - \log\sin(58-54)$.

Establishing and solving the transfer equations we get the reciprocal of the weight $\frac{1}{p} = 32{\cdot}380$, also the mean error m_F and the probable error r_F, both expressed in units of the sixth place of decimals in their logarithms, viz: $\pm 3{\cdot}92$ and $\pm 2{\cdot}64$, respectively; hence log. distance Summersville to Ivy $4{\cdot}888\,948\,6 \pm 2\,6$ and the distance $77\,437{\cdot}02 \pm 0{\cdot}47$ metres. The probable error is about $\frac{1}{165\,000}$ part of the length.

To this must be added the proportional error depending upon that of the base measure, or $0{\cdot}003\,5 \times \frac{77\,437}{3\,870} = \pm 0{\cdot}07$ metre; hence

Probable error of length of side Summersville to Ivy $\sqrt{(0{\cdot}47)^2 + (0{\cdot}07)^2} = \pm 0{\cdot}48$ metre.

For the side Piney to Pigeon we use the expression—

$$\frac{\text{Piney to Pigeon}}{\text{St. Albans Base}} = \frac{\sin(20-21+28-29)\sin(43-42)\sin(53-52)\sin(57-55)}{\sin(21-20)\sin(28-26)\sin(35-32)\sin(46-44)}\,\frac{\sin(62-60)\sin(64-63)}{\sin(51-50)\sin(58-54)}$$

$F = \log\sin(20-21+28-29) + \log\sin(43-42) + \log\sin(53-52) + \log\sin(57-55) + \log\sin(62-60) + \log\sin(64-63) - \log\sin(21-20) - \log\sin(28-26) - \log\sin(35-32) - \log\sin(46-44) - \log\sin(51-50) - \log\sin(58-54)$.

Establishing and solving the transfer equations we get $\frac{1}{p} = 22{\cdot}696$; also $m_F = \pm 3{\cdot}28$ and $r_F = \pm 2{\cdot}21$; hence log. distance Piney to Pigeon $4{\cdot}378\,842\,6 \pm 2\,2$ and distance $23\,924{\cdot}49 \pm 0{\cdot}12$ metres. The probable error is about $\frac{1}{196\,000}$ part. We add to this the proportional error arising from the base measure, or $0{\cdot}003\,5 \times \frac{23\,924}{3\,870} = \pm 0{\cdot}02$ metre; hence—

Probable error of length of side Piney to Pigeon $\sqrt{(0{\cdot}12)^2 + (0{\cdot}02)^2} = \pm 0{\cdot}12$ metre.

GENERAL DESCRIPTION OF STATIONS FORMING ST. ALBANS BASE NET, WEST VIRGINIA.

St. Albans East Base, Kanawha County; established by W. B. Fairfield in 1891. This station is situated about 2 miles east of the Chesapeake and Ohio Railroad station in the town of St. Albans, about 150 feet west of the west bank of Swindlers Creek and 60 feet north of the north rail of the main line of the Chesapeake and Ohio Railroad track. It is in the southeast corner of a large field belonging to Mr. Samuel Shrewsberry. The geodetic point is marked by a copper bolt with fine hole drilled at the intersection of cross lines cut on it in the top of a limestone post 6 inches square and 2 feet long, buried with its top 4 feet below the surface. Over this was placed a concrete block 3½ feet square and 1 foot thick, having a hole 9 inches square in the center. On this foundation was placed a monument of Indiana limestone 18 inches square and 4 feet high, the upper foot projecting above the surface of the ground and being cut in a pyramidal form with a copper bolt in its apex. A fine hole, drilled at the intersection of cross lines cut on this bolt, marks the geodetic point.

St. Albans West Base, Kanawha County; established by W. B. Fairfield in 1891. This station is situated in the town of St. Albans, on the west side of First street, 60 feet north of the north rail of the main line of the Chesapeake and Ohio Railroad track and on the line of the fence forming the eastern boundary of the land belonging to Mr. Daniel J. Lewis, who lives in the brick house on this lot. The markings and monument at this end of the base are similar in every respect to those at the East Base station.

Ryan, Kanawha County; established by W. B. Fairfield in 1891. This station is situated about 2 miles northeast of the town of St. Albans on the north side of the Kanawha River. It is on the top of a small, cleared, rounded hill on the land of Mr. Pat Ryan, and is on the highest part of the Ryan farm. The geodetic point is marked by the apex of an earthenware pyramid, buried 3 feet below the surface, over which was placed a 6-inch draintile pipe filled with concrete and having a 6-inch spike in the center of the top, which projects about 2 inches above the surface and is marked U.S.C.&G.S. 1893. As reference marks, four 4-inch draintile pipes filled with concrete, with a nail in the center of each, were set as follows: One due north, distant 5·95 feet; one due east, distant 6 feet; one due south, distant 6·04 feet, and one due west, distant 6 feet from the geodetic point. The tops of these pipes project about 3 inches above the surface of the ground.

Rogers, Kanawha County; established by W. B. Fairfield in 1891. This station is situated on a sharp, rocky hill with a small top on the west side of Coal River, about one-half mile from the town of St. Albans in a southwest direction, on land belonging to Mr. L. R. Rogers. The geodetic point is marked by a cross cut on a copper bolt sunk in the solid rock 15 inches below the surface of the ground, over which was placed a 6-inch draintile pipe filled with concrete and with spike in the center, projecting about 3 inches above the surface of the ground.

The reference marks are holes drilled in the rock, north, east, and south, and a 4-inch draintile pipe, filled with concrete and with a nail in the center, to the west, at the following distances from the geodetic point: North hole, 13 feet; east hole, 11·20 feet; south hole, 5·58 feet, and pipe to west, 6·64 feet.

Coal, Kanawha County; established by W. B. Fairfield in 1891. This station is

situated about 2 miles from the town of St. Albans, in a southerly direction. It is on the highest point of the ridge known as the Indian Creek Hills, on a sharp rocky point, small on top and with very few trees on it, belonging to Mr. Tom Vickers. The geodetic point is marked by the apex of an earthenware pyramid, buried 3 feet below the surface, over which was placed a 6-inch draintile pipe, filled with concrete, with a 6-inch spike in the center as a surface mark. As reference marks, 3 holes about 1 inch in diameter and 6 inches deep were drilled in the solid rock, as follows: One bearing south 3° 38′ west (true), distant 17·55 feet; one bearing north 16° 26′ west (true), distant 9·60 feet, and one bearing north 32° 20′ east, distant 13 feet, from the geodetic point.

Simms, Putnam County; established by W. B. Fairfield in 1891. This station is situated on the west side of the Kanawha River, about 5 miles in a northerly direction from St. Albans. It is on the land of Mr. Robert Simms, and on the highest point of the first river hill north from Scary station on the Chesapeake and Ohio Railroad, about 2 miles distant. The geodetic point is marked by the apex of an earthenware pyramid buried 3 feet below the surface of the ground. Over this is placed a 6-inch draintile pipe, filled with concrete, and having a 6-inch spike in the center as a surface mark. A circle of cement 6 inches thick and 2 feet in diameter, marked with the letters U.S.C.S., was put around the top of the pipe.

As reference marks four 4-inch draintile pipes, filled with cement, with a nail in the center of each, were set as follows: One due north, distant 5·85 feet; one due east, distant 7·50 feet; one due south, distant 5·95 feet, and one due west, distant 6·85 feet, from the geodetic point.

Big Rocks, Kanawha County; established by A. T. Mosman in 1881. This station is situated on the highest point on Big Rocks Hill, about 5¾ miles, air line, in a southwesterly direction from St. Albans. The distance by road is between 7 and 8 miles. It is about 150 yards to the right of a road winding up the ridge for a distance of about one-half mile from the house of Mr. Oxley, who lives at the foot of the hill on the eastern side. The geodetic point is marked by the apex of an earthenware pyramid buried 3 feet below the surface of the ground. Over this was placed a draintile pipe, 6 inches in diameter and 2 feet long filled with concrete with 6-inch spike in the center and projecting about 2 inches above the surface. As reference marks, four 4-inch draintile pipes, filled with concrete and with nail in center of each, were placed as follows: One due north, distant 6·11 feet; one due east, distant 4·92 feet; one due south, distant 6·18 feet, and one due west, distant 5·87 feet from the geodetic point.

Piney, Cabell County; established by A. T. Mosman in 1880. This station is situated on a ridge near the line between Cabell and Putnam counties, about 2 miles in an air line and about 4¼ miles by road northwest of Hurricane station on the Chesapeake and Ohio Railroad. The geodetic point is marked by the apex of an earthenware pyramid buried about 2 feet below the surface in a hole in sandstone rock. Above this were placed two concrete blocks, each 6 inches thick, the lower one 8 inches and the upper one 3 feet square. On this foundation was built a concrete pier 2 feet in diameter, having a 6-inch spike in the center just below the surface of the ground. In 1891 this pier was built up with cement, forming a dome 2 feet in diameter and about 6 inches above the surface with a spike in the center and the letters U.S.C.S. marked in the cement.

As reference marks, 4 concrete blocks 8 inches square with a 6-inch spike in the center of each, were placed even with the surface as follows: One north, distant 6·22 feet; one south, distant 5·95 feet; one east, distant 5·90 feet, and one west, distant 6·05 feet from the geodetic point.

Holmes, Kanawha County; established by A. T. Mosman in 1880. This station is situated 8½ miles northward from Charleston, West Virginia, on the ridge dividing the waters flowing into Coopers Creek, and thence into Elk River from those flowing by Two Mile Creek into the Kanawha River. It is on the land of Mr. S. W. Gibson, about one-half mile northeast from the house of Marshall P. Holmes at the head of the left fork of Two Mile Creek (of Kanawha). The geodetic point is marked by a bottle set in cement and over this a sandstone post 6 by 6 by 30 inches with cross lines and the letters U.S.C.& G.S. cut on top, reaching to the surface of the ground.

As reference marks, four sandstone posts of the same dimensions with diagonal lines and an arrowhead pointing to the station cut on the tops were set as follows: One due north, distant 6·94 feet; one due south, distant 6·60 feet; one due east, distant 6·95 feet, and one due west 6·69 feet, from the geodetic point.

Table Rock, Kanawha County; established by A. T. Mosman in 1880. This station is situated about 12 miles in an air line south of Charleston, West Virginia, on a long, cleared, very narrow and steep ridge on the range of hills lying between the two forks of Lens Creek, which flows into the Kanawha at Brownstown, and is near the head waters of the creek. The geodetic point is marked by a small bottle set in cement 30 inches below the surface, in a hole dug in the sandstone ledge underlying the soil. Over this was placed a sandstone post 6 by 6 by 30 inches with cross lines and the letters U.S.C.& G.S. cut on top, reaching to the surface of the ground.

As reference marks, four sandstone posts of the same dimensions, with diagonal lines and an arrowhead pointing to the station cut on the tops, were set as follows: One due north, distant 7·01 feet; one due south, distant 6·97 feet; one due east, distant 7·05 feet, and one due west, distant 6·98 feet, from the geodetic point.

Pigeon, Lincoln County; established by A. T. Mosman in 1880. This station is situated about 18 miles in an air line southwest from St. Albans. It is on the land of Tom Huffman at the head of Middle Creek, which flows into Mud River, at a point about 3½ miles from Hamlin on the road to Griffithsville. A path leads to the top from Huffman's house. There is also a good path on the east side of the hill, about one-half mile long, from the house of William Stowers, on Laurel Creek, 8 miles from Hamlin. The geodetic point is marked by the apex of an earthenware pyramid buried 3 feet below the surface of the ground, over which was placed a sandstone post 6 by 6 by 30 inches, with cross lines and the letters U.S.C.&G.S. roughly cut on the top, reaching to the surface.

As reference marks, four sandstone posts of the same dimensions, with diagonal lines and an arrowhead pointing to the station, cut on the tops, were set as follows: One due north, distant 9·07 feet; one due south, distant 9·05 feet; one due east, distant 9·07 feet, and one due west, distant 9·01 feet, from the geodetic point.

Ivy, Raleigh County; established by A. T. Mosman in 1879. This station is situated on a knob of the Cherry Pond Mountains, known as Ivy Knob, near the corner of Wyoming and Boone counties, West Virginia. It is on the highest part of the knob, which is of a rounded form with a very steep ascent—1 700 feet to a mile. The top

was completely cleared with the exception of one tree left standing near the station. It is about 50 miles by road from Brownstown and about 43 miles from Quinnimont, two stations on the Chesapeake and Ohio Railroad, and about 3½ miles by bridle path from Mr. Thomas Webb's house on Peach Tree Creek. The geodetic point is marked by an iron spike set in cement in a hole drilled in the ledge 18 inches below the surface of the ground, over which is placed a sandstone block with a cross cut on its top.

As reference marks, four sandstone blocks, with cross and arrowhead pointing to the center cut on each, were set as follows: One north, 24 inches long, distant 7·07 feet; one south, 13 inches long, distant 6·95 feet; one east, 23 inches long, distant 6·99 feet, and one west, 30 inches long, distant 6·95 feet, from the geodetic point. A hole 4 inches deep is drilled in the solid rock under both the east and south blocks.

Summersville, Nicholas County; established by A. T. Mosman in 1879. This station is situated on a ridge distant 1 mile and bearing 6° north of west from Nicholas court-house belfry, in the town of Summersville. The prolongation of the main street of Summersville, which runs nearly east and west, cuts the ridge very near the station. The nearest railroad station is Kanawha Falls, on the Chesapeake and Ohio Railroad, 32 miles distant. The geodetic point is marked by a bottle set in a hole in the ledge underlying the white clay at the station, over which was placed a sandstone block 30 inches long and 6 inches square, having cross lines cut on the top.

As reference marks, four sandstone blocks of the same dimensions, having cross and arrowhead pointing to the center cut on each, were set as follows: One north, distant 7·02 feet; one south, distant 7 feet; one east, distant 7·29 feet, and one west, 6·90 feet, distant from the geodetic point. Additional marks are a spike in a large tree standing alone, bearing north 5° 20′ west, distant 15·4 feet; a spike in a stump bearing south 29° 43′ east, distant 14 feet, and a spike in a stump bearing north 38° 09′ west and distant 20·8 feet, from the geodetic point.

(*h*) *Salina Base Line, Kansas, 1896.*

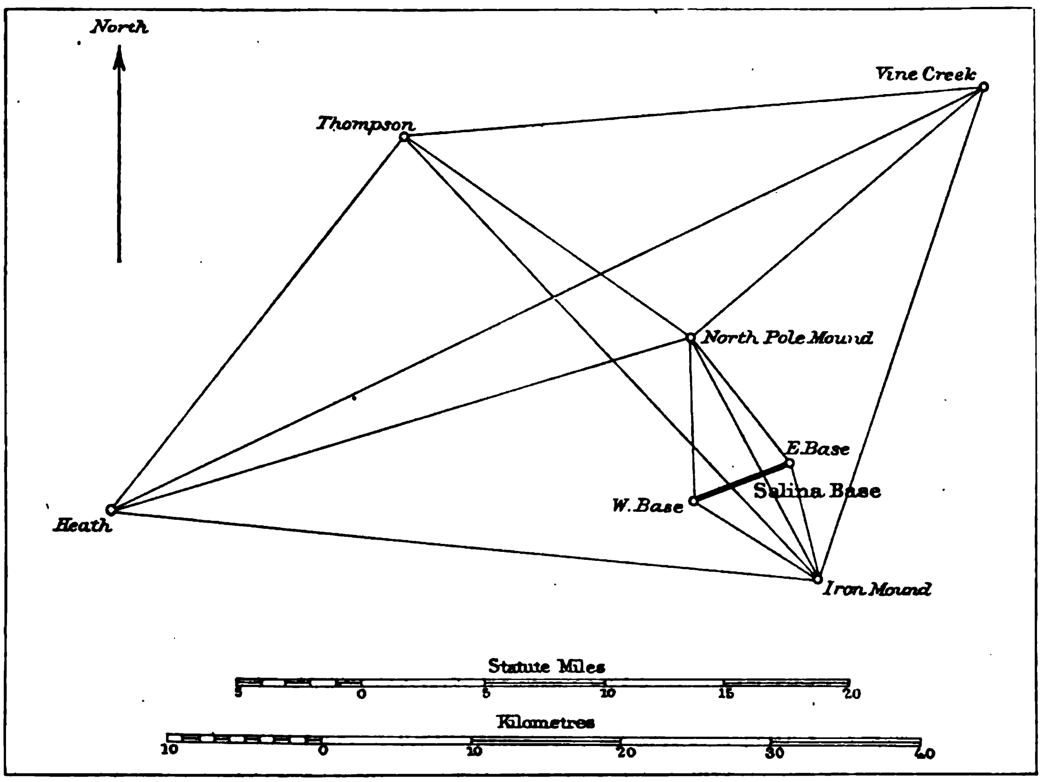
LOCATION, MEASUREMENT, AND LENGTH.

Location of the Base Line.—This base is located in central Kansas, near Salina, Saline County. The reconnoissance for a base was made in 1895; the site was selected and the line laid out by Assistant F. D. Granger in October, 1895. Its middle point is approximately in latitude 38° 52′ and in longitude 97° 34′, and its elevation is about 369 metres (1 210 feet) above the ocean. The length of the base is approximately 6·55 kilometres (4·07 statute miles) and its azimuth from the east end is 68⅔°.

The base is in the valley of the Saline River, north of and nearly parallel to the Union Pacific Railroad, between Saline and New Cambria. The general character of the ground is smooth and hard, rising gradually from East Base to West Base with a difference between the base ends of about 6½ metres (21 feet); both ends were connected with the transcontinental line of spirit levels. Beginning at the west end, the line crosses a cultivated field and enters the Salina and Cambria road, and following the north side of the road for a distance of 5·16 kilometres, it reaches East Base through cultivated fields. At a distance of 6·11 kilometres from West Base the line crosses a gully, which was bridged. The measuring bars rested on the bridge, but were handled by the observers, supported by plank walks constructed on each side of it. The east

end mark is situated about 1·6 kilometres (1 mile) west of New Cambria and the west end mark is in North Salina, east of the iron tanks of the Standard Oil Company, on land owned by the city. These base terminals are marked by two stone posts, one above the other; the subsurface mark is a copper bolt with cross lines set in a limestone and sunk three-fourths metre (2½ feet) below the surface of the ground; above this rests a double block of limestone, set in a layer of cement, also marked with copper bolt and reference lines. The exposed surface bears the inscription, U. S. Coast and Geod. Survey, 1896. Section stones with copper bolts and cross lines were set 1, 2, 3, 4, 5, and 6 kilometres from West Base, set in cement with their top surfaces 10 centimetres

No. 12.



(4 inches) below the level of the ground. The measuring force consisted of F. D. Granger, in charge of the party; W. C. Hodgkins, A. L. Baldwin, and E. B. Latham, with a foreman and six laborers.

The measurement of the base.—The base, excluding a practice measure of the first section and an extra measure of the west nalf of the third section, was measured twice by Assistant Granger between June 19 and July 23, 1896. He used the 5-metre contact-slide steel rods Nos. 13 and 14. They were constructed at the office shop in July, 1891, by Mr. E. G. Fischer, and embody the principle of contact and mode of construction proposed by Colonel Mudge,* but have received great improvements, due to Assistant J. E. Hilgard, as explained by him in Appendix No. 17, Coast and Geodetic Survey

* Triangulation of England and Wales. London, 1799.

Report for 1880, pp. 341–345, and they have since been further perfected. These are the same rods that were used in the measure of the Holton Base, Indiana, in 1891. For particulars and length of this base see Appendix No. 5, Coast and Geodetic Survey Report for 1894, pp. 103–116. On page 107 of that report we find the values of the coefficient of expansion of the rods as determined at the Survey office by Assistant Tittmann and Adjuster Fischer on May 18 to 26, 1891, as follows: For the centigrade scale—

$$\text{Coefficient of expansion of rod No. 13 or } \alpha_{13} = 0{\cdot}000\ 011\ 776 \pm 27$$

$$\text{Coefficient of expansion of rod No. 14 or } \alpha_{1} = 0{\cdot}000\ 011\ 714 \pm 29$$

or for mean rod $11{\cdot}745 \pm 0{\cdot}028$ microns per metre.

The length of the 5-metre rods Nos. 13 and 14.—These rods were standardized several times, the comparisons depending directly or indirectly on the length of the steel bar No. 17 when immersed in melting ice. The following four values for the combined length of the two rods are taken from Coast and Geodetic Survey Report for 1894, Appendix No. 5, pp. 103–110. To the first value, on page 110, however, 30 microns were added, since it was subsequently found that the knife edges and abutting surfaces were not in perfect contact during measurements. (Report for 1892, pt. 2, p. 491.)

Results for length of the combined rods Nos. 13 and 14 as in measurements, at temperature 22°·20 C. hyd.:

(1) July, 1891	Comparisons with B_{17} in vault	10 m. + 2·605 mm.	± 5μ
(2) August, 1891	Comparisons with hectometre in camp	2·608	5
(3) September, 1891	Comparisons with hectometre on base	2·609	6
(4) September, 1891	Comparisons with kilometre 3·9 to 4·9 on base	2·618	5(?)

In June, 1894, the rods were used for the measure of a base line in Maryland, and on the return of the rods the outer, or wooden, packing box of one of them was found damaged, which made it desirable to submit them to a new comparison before sending them into the field. The new observations were made in February, March, and April, 1896, in the grounds to the south of, and adjacent to, the Survey office at Washington, A. Braid, assistant in charge of weights and measures, conducting the operation.*

A 50-metre test line was laid out between two heavy blocks of concrete, and the ends were marked by the central axis of bronze bolts. The horizontal distance between them was measured a number of times with the 5-metre steel bar No. 17, immersed in melting ice. It was found that the two end blocks were not absolutely stable, apparently due to variations of moisture in the ground.

The results by bar No. 17 are corrected for differential micrometre measures at the ends of the line and for grade and alignment. The length of this bar is 5 metres $- 16{\cdot}2\mu \pm 1{\cdot}1\mu$; the results by the rods Σ (13 and 14) are corrected for micrometre and cut-off scale readings at the ends of the line; also for grade, alignment, and temperature difference; the corrections applied to thermometer readings for errors of calibration and reference to the hydrogen scale are given below.

* For further information see remarks in connection with the Salt Lake Base of 1896.

At	Centigrade thermometers on— Rod No. 13. Green 5609.	Green 5604.	Rod No. 14. Green 5606.	Green 5613.	Green 5612.
°	°	°	°	°	°
0	−0·27	−0·30	−0·35	−0·30	−0·05
3	·33	·59	·45	·47	·23
6	·28	·54	·51	·41	·14
11	·30	·53	·53	·40	·16
16	·34	·52	·54	·41	·17
21	·43	·56	·43	·43	·21
25	·33	·51	·56	·48	·26
32	·38	·56	·56	·50	·27
34	·39	·57	·52	·54	·32
37	−0·43	−0·63	−0·48	−0·50	−0·28

Thermometer No. 5606 was accidentally broken April 29, and during the base measure thermometer No. 5612 took its place.

Resulting length of 50-metre comparator or test line as measured by bar No. 17 and the rods Nos. 13 and 14.

Date, 1896.	Length by No. 17 50 m. +.		Date, 1896.	Corr'd temperature.	Length by Σ 13 and 14, 5 Σ +.	
				° C.	μ	μ
February 25	+ 50μ	+ 28μ	February 27	+ 6·91	+ 80	+ 80
25	+ 6		February 28	4·13	− 211	− 154
March 9	− 55		28	6·58	− 97	
9	− 47	− 79μ	February 29	9·37	+ 118	
9	− 136		29	9·80	+ 143	
March 31	−1 216		29	10·00	+ 160	+ 134
31	−1 278	−1 248μ	29	10·11	+ 105	
31	−1 251		29	10·24	+ 166	
April 2	−1 075		29	10·32	+ 112	
2	−1 092	−1 097μ	March 2	2·58	− 37	− 37
2	−1 125		March 7	7·18	− 20	
April 7	− 458		7	7·87	− 28	− 20
7	− 525	− 488μ	7	11·03	− 6	
7	− 489		7	11·72	− 26	
7	− 481		April 1	9·22	−1 031	−1 002
April 8	− 384		1	9·51	− 972	
8	− 384	− 387μ	April 2	7·46	−1 088	
8	− 394		2	7·41	−1 048	−1 048
			2	7·39	−1 035	
			2	7·35	−1 023	
			April 7	5·77	− 632	
			7	6·08	− 573	− 571
			7	6·31	− 523	
			7	6·49	− 555	
			April 8	6·97	− 606	− 559
			8	7·41	− 512	

N. B.—For dates between February 27 and March 7, inclusive, we take 50 m. − 26μ approximately. For April 1 we use 50 m. − 1 172μ approximately.

The probable error of a single measure of the 50-metre test line is ± 21μ.

From the preceding measures we derive the following values for the length of $\Sigma(13+14)$ at 0° C.:

Lengths of field comparator by bar No. 17.	Same length by $\Sigma(13+14)$ $5\Sigma+$	Resulting length of $\Sigma(13+14)$	$\Sigma(13+14)$	Relative weight.
m.		*m.*	*m.*	
49·999 974	+ 80μ	9·999 978 8		
974	− 154	10·000 025 6	Mean.	
974	+ 134	9·999 968 0	9·999 994 7	
974	− 37	10·000 002 2		
974	− 20	9·999 998 8		
49·998 828	−1 002		9·999 966 0	2
8 903	−1 048		9·999 990 2	4
9 512	− 571		10·000 016 6	4
9 613	− 559		10·000 034 4	2
		Weighted mean	10·000 001 2	±7·1μ

This value has been adopted in the computation of the Salina Base. To compare it with former determinations we get $\Sigma(13+14)$ at 22°·2 C. = 10·002 608 6 metres, showing an excellent accord with the mean of the four older values, 10 metres + 2·610 millimetres. The observations of 1891, July, show that rod No. 14 is nearly 19 microns longer than No. 13; hence when the individual lengths of the rods are required we have $l(13) = 4·999\ 991\ 1$ metres and $l(14) = 5·000\ 010\ 1$ metres at 0° C.

For measuring fractional parts of a rod at the kilometre marks, the 3-meter fractional bar No. 1 was used. It is provided with a sliding-scale attachment, and its errors of graduation are known and corrections were applied accordingly. The adjustment of the sectors which determine the inclination of the rod and the adjustment of the aligning telescopes were frequently tested. Transfers of end of rod to a ground mark were effected by mounting a theodolite sector a short distance off the line, pointing and moving the telescope down in a vertical plane. For the reduction to the sea level of the measured length of the base we have the following data:

The approximate height of the bridge bench mark or City Directrix (so-called) of St. Louis, Missouri, above the average level of the Gulf of Mexico is 125·8 metres ± 0·3 metre. The difference of height (Δh) by spirit level St. Louis B. M. and B. M. LXIII near Holliday at Mill Creek Bridge is + 106·7 metres; thence Δh to B. M. called F_1 on window sill of the Missouri Pacific Railroad depot at Salina, Kansas, is + 140·5 metres; thence to West Base copper bolt − 1·4 metres, making the elevation of West Base 371·6 metres. Further from spirit levels along the base line, June 8 to July 17, 1896, by E. B. Latham, we get the average elevation of the ground of the first kilometre 371·4 metres, the second 371·2 metres, the third 369·7 metres, the fourth 369·5 metres, the fifth 368 metres, the sixth 367·4 metres, the last half kilometre 366·1 metres, also the bolt at East Base 365·6 metres. These heights are to be increased by 1·1 metres for height of base bars above ground. For radius of curvature in the latitude and azimuth of the base, we have log. $\rho = 6·805\ 0$; average height of base bars, 370·4 metres (or 1 215 feet).
± 0·5

Table of results for length of base and its subdivisions.

[One average bar = 5·000 000 6 metres.]

No. of section.	Section.	Number of average bars.	Forward or backward measure.	Date of measurement, 1896.	Corrected average temperature of double bar.	Corrections for— Excess of temperatures of bars.	Corrections for— Inclination of bars.	Corrections for— Excess over mark.	Corrections for— Height above sea.	Resulting length of sections and base.
					° *C.*	*mm.*	*mm.*	*mm.*	*mm.*	*m.*
I	W. Base to 200	200	f.	July 23 to July 23	26·754	+314·36	−21·35	− 25·62	−58·38	1 000·209 1
			b.	July 21 July 21	25·006	293·82	28·12	+ 3·58		·211 0
									Mean	1 000·210 1
II	201 to 400	200	f.	June 23 June 27	27·063	317·99	23·39	- 138·56	−58·34	1 000·097 8
			b.	July 20 July 20	23·735	278·89	10·31	− 109·35		·100 9
									Mean	1 000·099 4
III	401 to 600	200	f.	June 27 June 29	25·692	301·88	35·64	− 175·49	−58·10	1 000·032 8
			b.	July 16 July 20	26·461	310·92	26·76	− 190·41		·035 8
									Mean	1 000·034 3
IV	601 to 800	200	f.	June 29 June 30	26·333	309·41	19·22	− 14·16	−58·08	1 000·218 1
			b.	July 14 July 14	27·306	320·84	16·10	− 28·08		·218 7
									Mean	1 000·218 4
V	801 to 1 000	200	f.	June 30 July 1	31·154	366·06	46·88	− 206·33	−57·83	1 000·055 1
			b.	July 13 July 13	24·216	284·54	42·71	− 125·45		·058 7
									Mean	1 000·056 9
VI	1 001 to 1 200	200	f.	July 3 July 6	26·123	306·95	53·35	− 148·10	−57·74	1 000·047 9
			b.	July 11 July 11	23·303	273·81	46·31	− 119·29		·050 6
									Mean	1 000·049 2
VII	1 201 to 1 310 or E. Base	110	f.	July 7 July 8	22·414	144·85	61·23	+1 725·59	− 31·75	551·777 5
			b.	July 9 July 10	22·850	+147·67	−95·33	+1 757·56		·778 2
									Mean	551·777 9
									Total length	6 552·446 2

It is noticeable that in every section the forward measure is smaller than the backward measure. That this is not due to an imperfect coefficient of expansion is shown by comparison of the temperature difference of Sections III and V. No adequate cause of the phenomenon could be assigned, though it seems to be connected with the fact that the reversal of the direction changes the insolated and shady sides of the apparatus. The question of a possible difference of temperature of the rods as indicated by the thermometers in contact therewith was looked into, but no definite result could be had for want of measures with *falling* temperature.

Additional measures of the base by means of a 50-metre steel tape (No. 137), June 8 to 18, 1896.—Three measures were made, the object being to gain some further experience respecting the value by such means. The work was conducted by A. L. Baldwin and E. B. Latham, aided by D. W. Eaton, a volunteer observer. All measures were made in daytime, generally in the early morning hours, the thermometer was read as each tape was laid, and was held at the same height as the tape, about 0·3 metre above

ground. The steel tape was tested for length on the bench standard at the Survey office in May, 1896, and again in February, 1897; its average value at 0° C. temperature and with a tension applied of 10 kilogrammes indicated at division 25, 25 metres + 0·8 millimetre, and at division 50, 50 metres + 1·6 millimetres; total weight 1 082 grammes; correction to spring balance − 0·3 kilogramme; assumed coefficient of expansion 0·000 011 4. During measure the tape was supported at its ends and in the middle and was under a tension of 9·7 kilogrammes. Making all due corrections for temperature, tension, inclination, catenary, and excess at the section marks, we have the following results for length of the sections by tape measures:

No.	Section.	Measure.	Measured length.		Reduction to sea level.	Resulting length by— Tape.	Bars.	Difference B.−T.
			m.		mm.	m.	m.	mm.
1	West Base to first kilometre mark	1	1 000·242 8			1 000	1 000	
		2	·264 4	·249 3	− 58·24	+ ·191 1	+ ·210 1	+19·0
		3	·240 6					
2	Second kilometre	1	1 000·129 8			1 000	1 000	
		2	·155 6	·142 2	− 58·21	+ ·084 0	+ ·099 4	+15·4
		3	·141 3					
3	Third kilometre	1	1 000·097 3			1000	1 000	
		2	·102 8	·096 6	− 57·97	+ ·038 6	+ ·034 3	− 4·3
		3	·089 6					
4	Fourth kilometre	1	1 000·281 6			1 000	1 000	
		2	·281 2	·277 9	− 57·94	+ ·220 0	+ ·218 4	− 1·6
		3	·270 9					
5	Fifth kilometre	1	1 000·106 4			1 000	1 000	
		2	·126 0	·112 7	− 57·71	+ ·055 0	+ ·056 9	+ 1·9
		3	·105 7					
6	Sixth kilometre	1	1 000·096 2			1 000	1 000	
		2	·115 1	·100 5	− 57·61	+ ·042 9	+ ·049 2	+ 6·3
		3	·090 1					
7	Last half kilometre	1	551·801 1			551	551	
		2	·813 1	·809 4	− 31·68	+ ·777 7	+ ·777 9	+ 0·2
		3	·814 1					
	First measure		6 552·755 2			6 552·375 8		
	Second measure		·858 2		−379·36	·478 8		
	Third measure		·752 3			·372 9		
	Mean		6 552·788 6			6 552·409 2	6 552·446 2	+37·0
						± ·010 8	± ·007 0	

The difference in the length of the base by bar and tape measures is 37 millimetres, about $\frac{1}{177\,100}$ part of the length. To obtain the probable error of the length of the base from the three tape measures, we form for each section the differences from its mean; let $S =$ the sum of these squares, then for all sections* $\Sigma S^2 = 0·001\ 551\ 65$

*Clarke's Geodesy, Oxford, 1880.

and the probable error for length of base $= 0\cdot674\ 5\sqrt{\dfrac{\Sigma S^2}{n\,(n-1)}} = \pm\ 0\cdot010\ 85$ metre. This is equal to $\frac{1}{604\ 000}$ part nearly. On the other hand, if we base the probable error on the discord of the three measures of the whole line, we find probable error $= \pm\ 23\cdot5$ millimetres, which we regard as a more just value than the preceding one. This last probable error is $\frac{1}{279\ 000}$ of the length. The relative weights of the results by bars (2 measures) and by tape (3 measures) is therefore as 11 to 1.

No further use was made of the tape measures.

Probable error of base from bar measures.

Supposing the differences between forward and backward measures of the several subdivisions to represent accidental errors of measure, the mean error of a unit of length, here assumed as 1 kilometre, equals $m_{\text{I}} = \sqrt{\dfrac{1}{2n}\left[\dfrac{dd}{s}\right]}$ and for a double measure $m_{\text{II}} = \tfrac{1}{2}\sqrt{\dfrac{1}{n}\left[\dfrac{dd}{s}\right]}$, where $n =$ number of sections $= 7$. Also the mean error of the total length L of the base is $m = m_{\text{II}}\sqrt{L}$ and probable error of same $r = 0\cdot674\ 5\ m_{\text{II}}\sqrt{L}$. We get

$$m_{\text{I}} = \pm\ 1\cdot77\ mm \quad \text{and} \quad m = \pm\ 3\cdot2\ mm$$
$$m_{\text{II}} = \pm\ 1\cdot25\ mm \qquad\qquad r = \pm\ 2\cdot2\ mm.$$

The effect of the uncertainty in the coefficient of expansion becomes quite large on account of the high temperature during the base measurement. The average temperature was $25^\circ\cdot5$ C., hence the probable error of base from this source is $(25\cdot5 - 7\cdot2) \times 28\mu \times 6\cdot55 = \pm\ 3\cdot4$ millimetres.

The probable error of the base, due to uncertainty in the height above the sea level, is $\pm\ 0\cdot5$ millimetre.

The probable error of the length of Σ (13 and 14) at 0° C. was found to be $\pm\ 7\cdot1\mu$; the corresponding value for the whole base is therefore $6\cdot55 \times 7\cdot1\mu$ or $\pm\ 4\cdot6$ millimetres.

The probable error in length of the bar-in-ice No. 17 is $\pm\ 1\cdot1\mu$; the corresponding probable error of the base is $\pm\ 1\cdot4$ millimetres.

Combining these five probable errors, we obtain that of the length of the base, or $\pm\ 6\cdot3$ millimetres, which is equal to $\frac{1}{1\ 040\ 000}$ of the length.

	m
Final result for length of base	6 552·446 2
	± ·006 3
and its logarithm	3·816 403 46
	± 42

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE SALINA BASE NET, 1890–91, 1896.

Salina East Base, Saline County, Kansas. May 26 to May 31, 1896. 30-centimetre theodolite, No. 118; 10·73 metres above station. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
11	Salina West Base	0	00	00·00	+·02	00·02	−0·13	59·89
12	North Pole Mound	74	29	25·26	−·03	25·23	+0·19	25·42
10	Iron Mound	277	07	18·65	−·01	18·64	−0·07	18·57

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''.59$.

Salina West Base, Saline County, Kansas. May 4 to May 10, 1896. 30-centimetre theodolite, No. 118; 6·10 metres above station. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
8	Salina East Base	0	00	00·00	+·02	00·02	+0·17	00·19
9	Iron Mound	52	50	52·60	−·03	52·57	−0·36	52·21
7	North Pole Mound	288	52	34·12	·00	34·12	+0·20	34·32

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''.57$.

North Pole Mound, Saline County, Kansas. June 5 to June 10, 1896. 30-centimetre theodolite, No. 118; 7·4 metres above station. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
15	Iron Mound	0	00	00·00	−·03	59·97	+0·04	00·01
16	Salina West Base	25	14	28·00	·00	28·00	−0·26	27·74
17	Heath	100	28	05·94	+·02	05·96	−0·09	05·87
18	Thompson	152	19	04·79	−·03	04·76	+0·47	05·23
13	Vine Creek	256	37	34·03	+·03	34·06	+0·18	34·24
14	Salina East Base	350	51	19·33	−·02	19·31	−0·35	18·96

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''.65$.

Iron Mound, Saline County, Kansas. July 30 to August 13, 1890. 35-centimetre theodolite, No. 10; 1·74 metres above station. F. D. Granger, observer. May 16 to May 22, 1896. 30-centimetre theodolite, No. 118; 1·67 metres above station. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
4	North Pole Mound	0	00	00·00	−·02	59·98	−0·08	59·90
5	Salina East Base	13	29	12·12	−·01	12·11	−0·04	12·07
6	Vine Creek	45	39	51·96	+·02	51·98	+0·33	52·31
	Frey	78	21	30·32	+·03	30·35		
	Taylor	106	49	58·94	+·01	58·95		
1	Heath	302	47	35·80	−·01	35·79	−0·02	35·77
2	Salina West Base	329	12	45·01	−·02	44·99	+0·30	45·29
3	Thompson	344	26	20·14	−·03	20·11	−0·48	19·63

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''.60$.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE SALINA BASE NET, 1890–91, 1896—Completed.

Vine Creek, Ottawa County, Kansas. June 28 to July 21, 1890. 35-centimetre theodolite, No. 10; 6·07 metres above station. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
19	Iron Mound	0	00	00 ·00	+ ·02	00 ·02	+0 ·31	00 ·33
20	North Pole Mound	30	57	43 ·92	+ ·03	43 ·95	−0 ·67	43 ·28
21	Heath	45	38	34 ·02	+ ·03	34 ·05	+0 ·06	34 ·11
22	Thompson	66	55	43 ·54	+ ·01	43 ·55	+0 ·29	43 ·84
	Wilmer	247	46	44 ·56	·00	44 ·56		
	Frey	276	35	31 ·59	− ·02	31 ·57		
	Taylor	288	06	51 ·69	− ·03	51 ·66		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·75.

Heath, Ellsworth County, Kansas. July 8 to July 25, 1891. 35-centimetre theodolite, No. 10; 17·30 metres above station. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level. ″	Resulting seconds. ″	Corrections from base-net adjustment. ″	Final seconds in triangulation. ″
	Lincoln	0	00	00 ·00	− ·01	59 ·99		
27	Thompson	46	04	27 ·51	+ ·03	27 ·54	+0 ·68	28 ·22
28	Vine Creek	72	07	24 ·06	+ ·02	24 ·08	−1 ·11	22 ·97
29	North Pole Mound	81	17	05 ·14	+ ·02	05 ·16	−0 ·35	04 ·81
30	Iron Mound	103	36	35 ·87	− ·01	35 ·86	+0 ·77	36 ·63
	Ellsworth water tower pole	241	44	04 ·27	+ ·03	04 ·30		
	Wilson	282	15	47 ·25	·00	47 ·25		
	Golden Belt	312	37	28 ·69	− ·03	28 ·66		
	Meads Ranch	323	40	31 ·61	− ·04	31 ·57		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·84.

Thompson, Ottawa County, Kansas. August 6 to August 10, 1891. 35-centimetre theodolite, No. 10; 1·68 metres above station. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level. ″	Resulting seconds. ″	Corrections from base-net adjustment. ″	Final seconds in triangulation. ″
26	Heath	0	00	00 ·00	+ ·04	00 ·04	−0 ·21	59 ·83
	Golden Belt	38	54	02 ·24	+ ·02	02 ·26		
	Lincoln	58	20	08 ·93	− ·01	08 ·92		
23	Vine Creek	227	20	01 ·45	+ ·01	01 ·46	+0 ·60	02 ·06
24	North Pole Mound	267	03	34 ·82	− ·03	34 ·79	−0 ·86	33 ·93
25	Iron Mound	279	10	48 ·50	− ·03	48 ·47	+0 ·46	48 ·93

Probable error of a single observation of a direction (*D* and *R*) = ±0″·56.

FIGURE ADJUSTMENT.

*Observation equations.**

No.	
1	$0 = +0.93 - (2) + (5) - (8) + (9) - (10) + (11)$
2	$0 = +0.71 - (4) + (6) - (13) + (15) - (19) + (20)$
3	$0 = +2.37 - (21) + (22) - (23) + (26) - (27) + (28)$
4	$0 = +0.80 + (13) - (18) - (20) + (22) - (23) + (24)$
5	$0 = -0.65 - (3) + (6) - (19) + (22) - (23) + (25)$
6	$0 = -1.76 + (13) - (17) - (20) + (21) - (28) + (29)$
7	$0 = -0.93 - (1) + (4) - (15) + (17) - (29) + (30)$
8	$0 = -0.70 - (4) + (5) - (10) + (12) - (14) + (15)$
9	$0 = +1.25 - (2) + (4) - (7) + (9) - (15) + (16)$
10	$0 = -111 + 23.6(1) - 35.2(3) + 11.6(6) + 9.0(19) - 54.1(21) + 45.1(22) + 29.8(27) - 43.1(28) + 13.3(30)$
11	$0 = -207 + 75.6(3) - 96.2(4) + 20.6(6) + 35.1(19) - 64.1(20) + 29.0(22) + 25.3(23) + 123.3(24) + 98.0(25)$
12	$0 = +46 + 21.6(2) - 87.8(4) + 66.2(5) + 7.2(7) - 23.1(8) + 15.9(9) + 100.0(14) - 130.8(15) + 30.8(16)$
13	$0 = -60 + 13.5(1) - 34.1(4) + 20.6(6) + 35.1(19) - 115.4(20) + 80.3(21) + 130.5(28) - 181.7(29) + 51.2(30)$

Correlate equations.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
(1)							−1			+23.6			+13.5
(2)	−1								−1			+21.6	
(3)					−1					−35.2	+75.6		
(4)		−1					+1	−1	+1		−96.2	−87.8	−34.1
(5)	+1	...	...	...	...	...	...	+1	...	....	....	+66.2	....
(6)		+1			+1					+11.6	+20.6		+20.6
(7)									−1			+7.2	
(8)	−1											+23.1	
(9)	+1								+1			+15.9	
(10)	−1	...	...	...	...	...	...	−1	...	....	....	....	....
(11)	+1												
(12)								+1					
(13)		−1		+1		+1							
(14)								−1				+100.0	
(15)	...	+1	...	...	...	...	−1	+1	−1	....	....	−130.8	....
(16)									+1			+30.8	
(17)						−1	+1						
(18)				−1									
(19)		−1			−1					+9.0	+35.1		+35.1
(20)	...	+1	...	−1	...	−1	...	...	...	....	−64.1	....	−115.4
(21)			−1			+1				−54.1			+80.3

* Number of conditions in the net 13, of these 9 relate to sums of angles and 4 to ratio of sides; in establishing the side equations 7 places in the logarithms are used and the logarithmic differences for 1″ are given in units of the seventh place.

FIGURE ADJUSTMENT—completed.

Correlate equations—Completed.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
(22)			+1	+1	+1					+45·1	+ 29·0		
(23)			−1	−1	−1						+ 25·3		
(24)				+1							−123·3		
(25)	...	...	...	...	+1	...	...	...	...	....	+ 98·0	....	....
(26)			+1										
(27)			−1							+29·8			
(28)			+1			−1				−43·1			+130·5
(29)						+1	−1						−181·7
(30)	...	...	...	...	...	...	+1	...	...	+13·3	....	....	+ 51·2

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
0 = + 0·93	+6							+2	+2			+83·6	
+ 0·71		+6		−2	+2	−2	−2	+2	−2	+ 2·6	+ 17·6	−43·0	− 95·8
+ 2·37			+6	+2	+2	−2				+26·3	+ 3·7		+ 50·2
+ 0·80				+6	+2	+2				+45·1	− 55·5		+115·4
− 0·65					+6					+82·9	+ 11·6		− 14·5
− 1·76						+6	−2			−11·0	+ 64·1		−116·5
− 0·93							+6	−2	+2	−10·3	− 96·2	+43·0	+185·3
− 0·70								+6	−2		+ 96·2	−76·8	+ 34·1
+ 1·25									+6		− 96·2	+60·9	− 34·1
−111										+9 894·9	−798·4		− 8 414·4
−207											+47 023·0	+ 8 446·4	+12 333·9
+ 46												+41 453·4	+ 2 994·0
− 60													+75 433·3

Resulting values of correlates and of corrections to angular directions.

Correlates		Corrections.	
	″	″	″
C_1 = −0·127 50	(1) = −0·027	(11) = −0·128	(21) = +0·062
C_2 −0·132 50	(2) = +0·304	(12) = +0·194	(22) = +0·289
C_3 −0·206 33	(3) = −0·483	(13) = +0·185	(23) = +0·602
C_4 −0·474 39	(4) = −0·081	(14) = −0·353	(24) = −0·862
C_5 +0·158 27	(5) = −0·038	(15) = +0·044	(25) = +0·466
C_6 +0·526 67	(6) = +0·325	(16) = −0·260	(26) = −0·206
C_7 +0·436 24	(7) = +0·199	(17) = −0·090	(27) = +0·683
C_8 +0·194 28	(8) = +0·164	(18) = +0·474	(28) = −1·107
C_9 −0·210 63	(9) = −0·363	(19) = +0·313	(29) = −0·347
C_{10} +0·015 98	(10) = −0·067	(20) = −0·664	(30) = +0·772
C_{11} +0·003 14			
C_{12} −0·001 59			
C_{13} +0·002 41			

Checks: Σ of + corrections 5·076 and $\Sigma\, pvv = +5·557$
Σ of − corrections 5·076 $-\Sigma wC = +5·551$

Mean error of an observed *direction* $m_1 = \sqrt{\frac{[pvv]}{n}} = \pm 0''·65$ where n = number of conditional equations; and mean error of *angle* $m_{<} = m_1\sqrt{2} = \pm 0''·92$, also probable error of same $\pm 0''·62$.

TRIANGLES OF THE SALINA BASE NET, KANSAS, 1890 TO 1896.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
1	Iron Mound	44	16	27·12	−0·34	26·78	0·04	3·816 403 5	6 552·446
	Salina West Base	52	50	52·55	−0·53	52·02	0·04	3·873 967 8	7 481·14
	Salina East Base	82	52	41·38	−0·06	41·32	0·04	3·969 127 4	9 313·81
				01·05			0·12		
2	North Pole Mound	34	23	08·69	+0·09	08·78	0·06	3·816 403 5	6 552·446
	Salina East Base	74	29	25·21	+0·32	25·53	0·06	4·048 428 5	11 179·66
	Salina West Base	71	07	25·90	−0·03	25·87	0·06	4·040 530 4	10 978·18
				59·80			0·18		
3	North Pole Mound	25	14	28·03	−0·30	27·73	0·07	3·969 127 4	9 313·81
	Iron Mound	30	47	14·99	−0·39	14·60	0·07	4·048 428 5	11 179·66
	Salina West Base.	123	58	18·45	−0·56	17·89	0·08	4·258 002 1	18 113·49
				01·47			0·22		
4	North Pole Mound	9	08	40·66	+0·40	41·06	0·03	3·873 967 8	7 481·14
	Salina East Base	157	22	06·59	+0·26	06·85	0·03	4·258 002 1	18 113·49
	Iron Mound	13	29	12·13	+0·04	12·17	0·02	4·040 530 4	10 978·18
				59·38			0·08		
5	Heath	22	19	30·70	+1·12	31·82	0·60	4·258 002 1	18 113·49
	North Pole Mound	100	28	05·99	−0·14	05·85	0·61	4·671 083 3	46 890·33
	Iron Mound	57	12	24·19	−0·05	24·14	0·60	4·602 976 6	40 084·51
				00·88			1·81		
6	Thompson	92	56	25·25	+0·65	25·90	0·62	4·602 976 6	40 084·51
	North Pole Mound	51	50	58·80	+0·56	59·36	0·62	4·499 188 0	31 563·71
	Heath	35	12	37·62	−1·03	36·59	0·61	4·364 404 4	23 142·19
				01·67			1·85		
7	Thompson	80	49	11·57	−0·67	10·90	1·06	4·671 083 3	46 890·33
	Iron Mound	41	38	44·32	−0·46	43·86	1·05	4·499 188 0	31 563·71
	Heath	57	32	08·32	+0·09	08·41	1·06	4·602 882 3	40 075·81
				04·21			3·17		
8	Thompson	12	07	13·68	+1·32	15·00	0·16	4·258 002 1	18 113·49
	North Pole Mound	152	19	04·79	+0·43	05·22	0·16	4·602 882 4	40 075·82
	Iron Mound	15	33	39·87	+0·40	40·27	0·17	4·364 404 4	23 142·19
				58·34			0·49		
9	Vine Creek	30	57	43·93	−0·98	42·95	0·37	4·258 002 1	18 113·49
	Iron Mound	45	39	52·00	+0·41	52·41	0·38	4·401 108 2	25 183·04
	North Pole Mound	103	22	25·91	−0·14	25·77	0·38	4·534 704 9	34 253·50
				01·84			1·13		

TRIANGLES OF THE SALINA BASE NET, KANSAS, 1890 TO 1896—completed.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
10	Thompson	51	50	47·01	−0·14	46·87	1·02	4·534 704 9	34 253·50
	Vine Creek	66	55	43·53	−0·02	43·51	1·02	4·602 882 4	40 075·82
	Iron Mound	61	13	31·87	+0·81	32·68	1·02	4·581 848 9	38 181·14
				02·41			3·06		
11	Vine Creek	35	57	59·60	+0·95	60·55	0·47	4·364 404 4	23 142·19
	North Pole Mound	104	18	29·30	−0·29	29·01	0·48	4·581 848 9	38 181·14
	Thompson	39	43	33·33	−1·46	31·87	0·48	4·401 108 1	25 183·03
				02·23			1·43		
12	Vine Creek	14	40	50·10	+0·73	50·83	0·34	4·602 976 6	40 084·51
	North Pole Mound	156	09	28·10	+0·27	28·37	0·35	4·805 732 3	63 934·06
	Heath	9	09	41·08	+0·76	41·84	0·35	4·401 108 1	25 183·03
				59·28			1·04		
13	Thompson	132	39	58·58	−0·81	57·77	0·75	4·805 732 3	63 934·06
	Vine Creek	21	17	09·50	+0·23	09·73	0·75	4·499 188 1	31 563·72
	Heath	26	02	56·54	−1·79	54·75	0·75	4·581 848 9	38 181·14
				04·62			2·25		
14	Vine Creek	45	38	34·03	−0·25	33·78	1·33	4·671 083 3	46 890·33
	Iron Mound	102	52	16·19	+0·35	16·54	1·33	4·805 732 3	63 934·06
	Heath	31	29	11·78	+1·88	13·66	1·32	4·534 704 9	34 253·50
				02·00			3·98		

PROBABLE ERRORS.

Determination of the probable errors of the length of the sides common to the net and to the adjacent chains of triangulation.

For the side Vine Creek to Iron Mound, as adjusted, we make use of the expression—

$$\frac{\text{Vine Creek to Iron Mound}}{\text{Salina Base}}=\frac{\sin(15-13)\sin(9-7)\sin(12-11)}{\sin(4-2)\sin(16-14)\sin(20-19)}$$

hence the function—

$$F=\log\sin(15-13)+\log\sin(9-7)+\log\sin(12-11)-\log\sin(4-2)$$
$$-\log\sin(16-14)-\log\sin(20-19)$$

Establishing and solving the transfer equations, we find the reciprocal of weight $\frac{1}{p}=14{\cdot}01$, also the mean error m_F and the probable error r_F, both expressed in units of the sixth place of decimals in their logarithms, viz: $\pm 2{\cdot}44$ and $\pm 1{\cdot}65$, respectively; hence log. distance Vine Creek to Iron Mound $4{\cdot}534\ 704\ 9 \pm 1\ 6$ and the distance $34\ 253{\cdot}50 \pm 0{\cdot}13$ metres. The probable error is about $\frac{1}{263\ 500}$ part of the length.

To this must be added the proportional error depending upon that of the base measure, or ·006 3 $\times \frac{34\ 253}{6\ 552} = \pm 0.033$ metre; hence probable error of length of side Vine Creek to Iron Mound $\sqrt{(0.13)^2 + (0.033)^2} = \pm 0.13$ metre.

For the side Thompson to Heath we use the expression—

$$\frac{\text{Thompson to Heath}}{\text{Salina Base}} = \frac{\sin(3-1)\sin(17-15)\sin(9-7)\sin(12-11)}{\sin(26-25)\sin(30-29)\sin(4-2)\sin(16-14)}$$

$$F = \log\sin(3-1) + \log\sin(17-15) + \log\sin(9-7) + \log\sin(12-11)$$
$$-\log\sin(26-25) - \log\sin(30-29) - \log\sin(4-2) - \log\sin(16-14)$$

Establishing and solving the transfer equation, we get—

$$\frac{1}{p} = 24.65, \text{ also } m_F = \pm 3.24 \text{ and } r_F = \pm 2.19;$$

hence log. distance Thompson to Heath $4.499\ 188\ 0 \atop \pm 2\ 2$ and distance $31\ 563.71 \atop \pm 0.16$ metres. The probable error is about $\frac{1}{197\ 300}$ part; adding to this the proportional error arising from the base measure, or 0·006 3 $\times \frac{31\ 564}{6\ 552} = \pm 0.030$ metre, we have—

Probable error of length of side Thompson to Heath $\sqrt{(0.16)^2 + (0.030)^2} = \pm 0.16$ metre.

GENERAL DESCRIPTION OF STATIONS FORMING THE SALINA BASE NET, KANSAS.

Salina West Base, Saline County; established by F. D. Granger in 1895. This station is situated in the northeast part of Salina, east of the tanks of the Standard Oil Company. The geodetic point is marked by the intersection of cross lines on a copper bolt set in a limestone post, 6 inches square and 2 feet long, sunk 2·5 feet below the surface of the ground. About 5 inches of earth covers the top of the post. Above this, except for a space of 8 inches square over the post, is a layer of concrete 4 inches thick and 36 inches square, on which rests a limestone block 30 inches square and 10 inches high, supporting another limestone block 30 inches square and 15 inches high, with beveled top and having a copper bolt with cross lines and a small drill hole sunk into its top as a surface mark. The two blocks are cemented together and are surrounded by a body of concrete several inches thick. The exposed top of the block bears the inscription U.S.C.&G. Survey, 1896. The following distances are given as reference marks: The geodetic point is 42·75 feet northwest of the line of telegraph poles which follow on the north side of and parallel to the track of the Union Pacific Railroad, and 10 feet east of a north and south fence which marks the eastern limit of ground owned by the Standard Oil Company, 79 feet northwest of the north rail of the main track of the Union Pacific Railroad. It is also 79·7 feet west of telegraph pole and 35·2 feet a little east of north of the fence corner of the Standard Oil Company's property.

Salina East Base, Saline County; established by F. D. Granger in 1895. This station is situated about 1 mile west of the village of New Cambria on land owned by Mrs. Mary Marlin, of Salina. The geodetic point is marked, both underground and at the surface, in practically the same manner as at West Base station, the only points of difference being that the underground post is 2·7 feet below the surface, with 8 inches

of earth and 5 inches of concrete over it. The geodetic point is 78·8 feet a little south of west from a wire fence on the Marlin farm; 22·43 feet a little west of north of a wire fence alongside the railroad; 35·05 feet from the second telegraph pole—marked with a triangle—west of the gate entrance to the Marlin farm, and 70·3 feet in the same direction from the north rail of the Union Pacific Railroad track.

Iron Mound, Saline County; established by F. D. Granger in 1886. This station is situated on a prominent and well-known butte in the northwest quarter of section 26, township 14 south, range 2 west of the sixth principal meridian, about 7 miles southeast of Salina. The geodetic point is marked by a stone ink bottle, filled with ashes and buried 2·7 feet below the surface of the ground. Over this was placed a marble post 6 inches square and 2·3 feet long, with cross lines and the letters U.S.C.S. cut on its top surface, which was flush with the ground. As reference marks, two hard limestone posts, each 5 inches square and 2·3 feet long and having a single diagonal groove and arrowhead cut on the top, were placed in the meridian of the station, one north and one south of the central marble post.

North Pole Mound, Saline County; established by F. D. Granger in 1890. This station is situated on a prominent and well-known hill in the northwest quarter of section 1, township 14 south, range 3 west of the sixth principal meridian and about 8·5 miles north of Salina. The geodetic point is marked by a bottle filled with ashes, buried 1 foot below the surface of the ground. Over this was placed a limestone block 1 foot square by 5 inches thick, with two cross lines and the letters U.S.C.S. cut on its top surface, which was covered with several inches of earth.

Heath, Ellsworth County; established by F. D. Granger in 1890. This station is situated in the southwest quarter of section 12, township 14 south, range 7 west of the sixth principal meridian, on land owned by William Heath, who lives in a stone house about one-third of a mile to the southwest. The nearest towns are Brookville, 14 miles to the southeast, and Ellsworth, 18 miles to the southwest, both on the Union Pacific Railroad. The geodetic point is marked by a glass bottle filled with ashes, the top being 3 feet below the surface of the ground. Over this was placed a marble post 6 inches square and 2·25 feet long, having two cross lines and the letters U.S.C.S. cut on its top surface, which was flush with the ground. As reference marks, two hard limestone posts, each 6 inches square and 2·25 feet long, with a single diagonal groove and arrowhead cut on top, were placed in the meridian of the station, one 7·51 feet south and one 7·16 feet north of the central marble post.

Thompson, Ottawa County; established by F. D. Granger in 1890. This station is situated about 12 miles southwest of the town of Minneapolis, in the northwest quarter of section 25, township 11 south, range 5 west of the sixth principal meridian, on a prominent round-top hill belonging to Judge R. F. Thompson, of Minneapolis, Kansas. The geodetic point is marked by a bottle filled with ashes, buried 3 feet below the surface of the ground. Over this was placed a marble post, 6 inches square and 2·25 feet long, having two cross lines and the letters U.S.C.S. cut on its top surface, which was flush with the ground. As reference marks, two hard limestone posts, each 6 inches square and 2·25 feet long, with a single diagonal groove and arrowhead cut on top, were placed in the meridian of the station, one 13·18 feet north and one 14·10 feet south of the central marble post.

Vine Creek, Ottawa County; established by F. D. Granger in 1886. This station

is situated in the northwest quarter of section 13, township 11 south, range 1 west of the sixth principal meridian. The nearest railroad stations are Vine Creek, 2½ miles to the northwest, and Manchester, 4 miles east, both on the Santa Fé Railroad. The geodetic point is marked by a bottle filled with ashes, buried 2·6 feet below the surface of the ground. Over this was placed a marble post, 6 inches square and 2·3 feet long, having two cross lines and the letters U.S.C.S. cut on its top surface, which was flush with the ground. As reference marks, two limestone posts, each 5 inches square and 2·5 feet long, with a single diagonal groove and arrowhead cut on top, were placed in the meridian of the station, one north and one south, each distant 10·01 feet from the central marble post. Additional reference marks are as follows: The northeast corner of McDade's house bears south 53° 30′ west, distant 270·5 feet; stone at northwest corner of section 13 bears north 7° 41′ west, distant 466·7 feet; southwest corner of old stone stable bears north 83° 08′ east, distant 218·6 feet; stone on the sixth principal meridian at the southeast corner of the northeast quarter of section 13 bears south 67° 12′ east, distant 5 680 feet, and the northwest corner of stone "dugout" bears south 65° 31′ east, and distant 124·6 feet from the central marble post. All bearings are true.

(*i*) *Salt Lake Base Line*, *Utah*, *1896*.

LOCATION, MEASUREMENT, AND LENGTH.

This base line is located between Kaysville, Davis County, and Hooper, Weber County, Utah, about 16 kilometres or 10 statute miles south-southwest of Ogden, and within about 5 miles of the railroad connecting with Salt Lake City. It extends along the eastern shore of the Great Salt Lake, over hard and somewhat sandy ground, including pastures and some cultivated fields. It is flat throughout, but crosses two main irrigation ditches (which had to be bridged), the railway, a turnpike, minor water ditches, dikes, furrows, and innumerable barbed-wire fences. The northwest and southeast ends are located on pasture grounds; the line is at an approximate elevation of 1 297 metres (4 255 feet) above the sea level, and its length is 11·20 kilometres (or 7 statute miles) nearly.

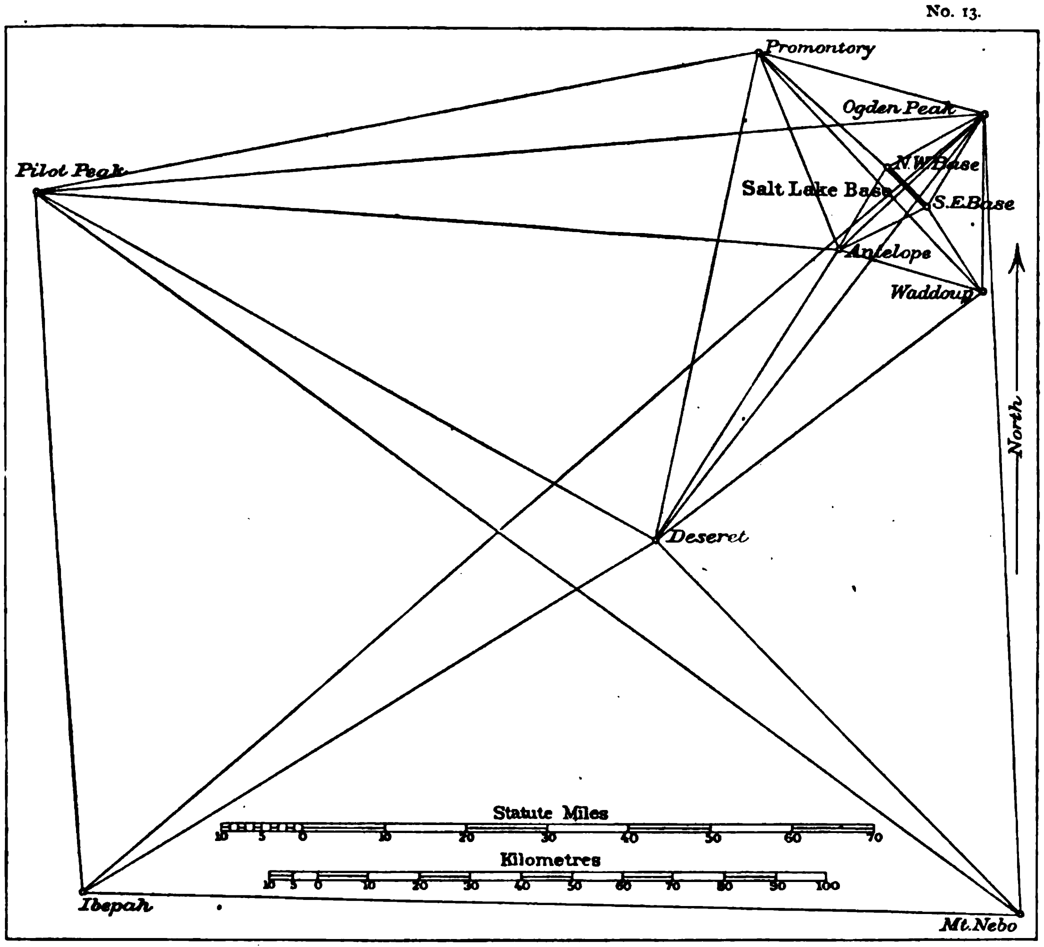
The middle of the base is in latitude 41° 04′ and in longitude 112° 04′, and its azimuth at the southeast end is 132° 05′ nearly. The terminals of the base are marked by brick monuments rising 9 feet above the ground, with bases 4 feet square, and tapering upward. Each monument has a capstone, a second stone flush with the surface of the ground, and a third one 3 feet below, each having a copper bolt in its center to secure the end of the line. The kilometre or line stones, 10 in number, have their upper surfaces flush with the ground and are likewise provided with copper bolts.

The site was first reconnoitered in 1883 by Assistant Eimbeck, and was again visited by him in 1886 and in 1887, but the final location of the base was made in 1896. To obtain its height above the sea, a line of spirit levels (forward and backward) connects the Ogden railroad station (old depot) with the Ogden Observatory. The Hooper bench mark on the lake is connected with the latter place, also with Northwest Base and along the base, with Southeast Base. The ends of the base are connected with the surrounding trigonometric stations by reciprocal zenith distances.

The base was measured in September and October, 1896, under the direction of Assistant Eimbeck, with the new base apparatus known as the "duplex," designed by

him and here used for the first time. A detailed description of this apparatus is given in Appendix No. 11, Coast and Geodetic Survey Report for 1897. The base was measured twice, under canvas cover; once forward and once backward. It includes eleven subdivisions. Each half kilometre was measured as near as possible with stationary or with rising and with falling temperatures, and with interchange of the component bars with respect to "up and down." A description of the measure will be found in Appendix No. 12, Coast and Geodetic Survey Report for 1897.

No. 13.



The standardization of the duplex contact-slide base apparatus.—This consists in determining the length of one of the rods in terms of the observed difference of length of the steel and brass components at a given temperature and includes also, as a precautionary or auxiliary measure, the length of each rod at a given temperature and its coefficient of expansion. During these and all subsequent operations the bars were covered with felt cloth.

The metallic duplex 5-metre base bars Nos. 15 and 16 were standardized at the Survey office at Washington both before and after the measure of the Salt Lake Base Line.

For this and other purposes a test line 50 metres in length was established in the yard adjacent to and south of the office building. The location is unfavorable, being on made ground and covering a surface originally sloping, but was the best that could conveniently be had. It, however, necessitated the frequent redetermination of its length, which was readily effected by means of the 5-metre bar-in-ice No. 17. The terminal marks are bronze bolts about 18 millimetres in diameter and ending in a spherical segment the center of which is determined by means of the so-called cut-off apparatus. Each bolt is embedded in a block of concrete about 1½ metres square and 1½ metres high. Between these marks wooden posts are driven at intervals of 5 metres, which, together with two brick piers at the ends 1·2 metres higher than the concrete containing the terminals, serve for the support of microscopes as may be required during measures. Alongside of these supports there runs a wooden track capped with iron rails for the easy transportation of the measuring bars. The whole line is covered by a shed with openings in the sides for ventilation, those on the north side being opposite the posts and piers for illumination of the line measures.

The first operation, in charge of Assistant A. Braid, chief of Office of Weights and Measures, consisted of the measures of the length of the office test line, the variations of which were found to reach a range of nearly 2 millimetres during the interval from February to May, 1896, and of the standardizing of the two bars of the duplex apparatus. The second operation at this place, and after the measure of the Salt Lake Base, comprised similar work in charge of Assistant W. Eimbeck during November, 1896. In accordance with the principle of construction of the duplex base apparatus what must be known first is the length of the steel and brass components for a given temperature, and second according to the duplex principle, the lengths of the steel (or brass) bar corresponding to a given *difference* of length of the two components; thus the use of thermometers may, if we choose, be dispensed with in the work of standardization as well as in that of the base measure. It is only assumed that the steel and brass bars are of the *same* temperature. Thermometers were employed, however, in the work on the test line and as a precautionary measure also in the first practical application of the apparatus in the field.

The method of using the bar-in-ice No. 17 for laying out a standard length is described in Appendix No. 8, Coast and Geodetic Survey Report for 1892, pp.329–503, where the length of the steel bar at the temperature of melting ice was found to be 5 metres $-16{\cdot}2\mu \pm 0{\cdot}4\mu$.* (See also account of the Holton Base measure.)

Measure of the 50-metre office test line with the 5-metre bar-in-ice No. 17.—Microscopes A and B were mounted over the west and east piers, respectively; microscopes 1, 2, 3, and 4 were mounted on posts within the line (at distances of 5 metres). The value of one turn of micrometre of A, was $72{\cdot}06\mu$, and of B, $71{\cdot}2\mu$, and one division of each of the micrometres of the intervening microscopes was equal to 1μ. Cut-off cylinder No. 1 was used at both ends of the line. Its length was 104·8 centimetres; one division of level was equal to 6″.17, equivalent to $31{\cdot}3\mu$. On April 3 a new level was substituted with a division = 2″.43, equivalent to $12{\cdot}3\mu$. The cut-off scale is divided into millimetres. A sector was read for grade correction. The first series of measures covered the period February to May, 1896; the second series was made in November, 1896. The results are given below:

* This probable error which refers to Prototype Metre No. 21 must be changed to $\pm 1{\cdot}1\mu$ to refer it to the International Metre. Appendix No. 8, Report for 1892, p. 391.

First series.

No.	Date, 1896.	Hour.	Direction.	Length 50m.	Daily mean 50m.
		p.m.		μ	μ
1	February 25	0·7	E.	+ 50	+ 28
2	"	2·3	W.	+ 6	
3	March 9	0·4	E.	− 55	
4	"	2·0	W.	− 47	− 79
5	"	2·9	E.	− 136	
6	March 10	0·3	W.	− 48	
7	"	1·0	E.	− 97	
8	"	1·8	W.	− 95	− 57
9	"	2·2	E.	− 15	
10	"	2·8	W.	− 52	
11	"	3·3	E.	− 35	
12	March 31	1·8	W.	−1 216	
13	"	2·8	E.	−1 278	−1 248
14	"	3·6	W.	−1 251	
15	April 2	1·7	E.	−1 075	
16	"	2·3	W.	−1 092	−1 097
17	"	3·0	E.	−1 125	
18	April 4	2·8	W.	− 817	− 822
19	"	3·5	E.	− 827	
20	April 7	a.m. 11·6	W.	− 458	
21	"	p.m. 0·3	E.	− 525	− 488
22	"	3·2	W.	− 489	
23	"	3·8	E.	− 481	
24	April 8	a.m. 11·5	W.	−384	
25	"	p.m. 0·9	E.	−384	−387
26	"	3·1 (?)	W.	−394	
27	April 14	0·4	W.	− 76	
28	"	1·2	E.	− 17	− 41
29	"	5·4	W.	− 29	
30	April 18	a.m. 11·0	E.	+117	
31	"	11·5	W.	+192	+151
32	"	p.m. 3·7	E.	+145	
33	May 7	0·4	E.	+677	
34	"	1·1	W.	+744	+699
35	"	4·4	E.	+676	
36	May 8	a.m. 10·6	W.	+712	
37	"	11·2	E.	+675	+696
38	"	p.m. 3·5	W.	+701	

Subtracting each result from its daily mean, squaring and summing, we find the probable error of a single measure of the test line $= 0·675\sqrt{\frac{[vv]}{(n-n_1)}} = 0·675\sqrt{\frac{25\,200}{38-12}}$ $= \pm 21\mu = \frac{1}{2\,400\,000}$ part of the length. The great change in length between March 10 and 31 was unexpected, and since no interpolation for length during this period could be made, all (23 in number) measures with the duplex bar made during this period had to be rejected.

Second series, after the measure of the Salt Lake Base. November, 1896.

No.	Date, 1896.	Hour.	Direction.	Length 50m.	Daily mean 50m.
		p.m.		μ	μ
1	November 17	2·5	E.	+4 165	+4 165
2	18	a.m. 10·6	W.	+4 072	+4 077
3	18	11·6	E.	+4 081	
4	19	10·9	E.	+4 126	+4 166
5	19	11·5	W.	+4 207	
6	20	10·7	E.	+4 161	+4 135
7	20	11·4	W.	+4 108	
8	November 24	a.m. 11·4	E.	+4 145	+4 160
9	24	12·0 (?)	W.	+4 176	
10	25	10·6	E.	+4 114	
11	25	11·3	W.	+4 147	+4 144
12	25	p.m. 4·0	E.	+4 172	

Apparently no change took place in the length of the base; hence mean length $= 50 \text{ metres} + 4\,140\mu \pm 8$ and $\pm 14\mu$ when referred to the International Metre; also the probable error of a single measure $\pm 27\mu$ or $\frac{1}{1\,840\,000}$ of length.

Determination of the length of the duplex bars Nos. 15 and 16, from measures of the 50-metre test line.—The standardization of these bars can be effected with or without the use of thermometers. The results by the thermometric method will be given first. The measures cover the same dates as those on which the exact length of the test line was ascertained by means of the bar-in-ice measures. Centigrade thermometers Nos. 8850, 8848, and 8818 were placed between the rods of No. 15, and C. thermometers Nos. 8856, 8854, and 8815 between the rods of No. 16, at one-sixth of the length from the ends of the rods and at the middle, respectively. Corrections to thermometers referred to the hydrogen scale.

Thermometers.

Temperature.	8 856	8 854	8 815	8 850	8 848	8 818	8 847
°	°	°	°	°	°	°	°
0	·00	·00	·00	·00	·00	·00	·00
5	— ·02	— ·02	— ·16	— ·04	— ·04	+ ·01	
10	— ·02	— ·02	— ·07	— ·02	— ·05	+ ·03	
15	— ·03	— ·03	— ·09	— ·08	— ·08	— ·01	— ·04
20	— ·06	— ·04	— ·10	— ·06	— ·06	— ·04	
25	— ·07	— ·06	— ·17	— ·11	— ·11	— ·06	
30	— ·12	— ·12	— ·13	— ·12	— ·12	— ·00	
35	— ·08	— ·10	— ·16	— ·08	— ·13	— ·10	
40	— ·09	— ·14	— ·12	— ·06	— ·11	— ·11	
45	— ·13	— ·16	— ·11	— ·13	— ·11	— ·06	

The mean of the three thermometers attached to each bar was used in the computation.

The value of the divisions of the four scales on bars 15 and 16, which measure the *relative* longitudinal shifting of the bars, was found to be 1 millimetre, very nearly, at a temperature of 11°·7 C.

A table was formed which contains, for each measure of the test line, the excess or defect of the 10 steel rods (of 15 and 16) and the 10 brass rods (of 15 and 16) on a 50-metre line. Due regard was paid to the actual distance between the terminals as found on the *same day* of measure with the bar-in-ice, and to all corrections for slope, inclination, and scale of the cut-off apparatus. The observations, however, of April 14, 18, May 7, 8, were not made with the apparatus under the same conditions as afterwards employed. In the first place, no inversion of the bars took place; i. e., observations with "face up and face down." An attempt was made to supply this omission by the direct measure of the difference between the two fiducial lines of each of the four rods, but these last measures proved unsatisfactory. In the second place, it should be noted that in the measures over the test line the same metal of the rods was always exposed to the south—that is, to greater heat radiation than the other. This circumstance was brought about by the *backward* manipulation of the

apparatus when changing the direction of the measure.* For these reasons it was thought best to depend for the standardization of the apparatus on the November observations alone.

The following table exhibits the 32 measures of the test base (50 metres—4 140μ) with the duplex bars, giving the separate results for the steel and brass components; the last three columns give the excess of length of 10-metre steel rods over 50 metres the same for 10-metre brass rods (the negative signs shows that they fall short of it), and the difference in the length of 10-metre steel and 10-metre brass rods for the temperatures noted. These quantities are given in microns.

Standardization of the bars Nos. 15 and 16 of the Duplex Apparatus over the office 50-metre test line.

No. of series.	Date, September, 1896.	Hour p.m.	Direction of measure.	Face up or down.	Mean temperature t centigrade.	Inclination of cut-off.	Cut-off E.-W.	Grade correction.	Cut-off correction.	Steel component W.-E.	Shift of steel rod.	Brass component W.-E.	Shift of brass rod.	Length of 10 steel bars —50 metres.	Length of 10 brass bars —50 metres.	Difference of steel and brass rods.
		h			°	μ	μ	μ	μ	μ	μ	μ	μ	μ	μ	μ
1	18	1·9	E.	U.	19·37	−69	+539	−7	+ 7 000	+ 61		+ 39	+2 162	− 3 384	− 5 524	+2 140
2	18	2·9	W.	U.	20·49	+ 3	−619	7	7	+557		+521	+1 750	2 794	4 508	1 714
3	18	3·6	E.	D.	21·17	+44	−233	6	8	+133	−1 493	+165		2 305	3 830	1 525
4	18	4·2	W.	D.	21·48	−19	−175	6	8	−135	−1 413	−102		2 112	3 558	1 446
5	19	1·1	E.	U.	18·28	+22	−468	9	9	−559		+1 163	+ 800	3 846	6 368	2 522
6	19	1·9	W.	U.	18·52	+19	+527	9	8	−435		−404	+2 330	3 962	6 323	2 361
7	19	2·3	E.	D.	18·37	− 8	+998	6	10	213	−2 693	−380		3 938	6 464	2 526
8	19	2·8	W.	D.	18·02	−35	+1 058	7	10	+100	−2 783	− 82		4 193	6 794	2 601
9	20	0·9	E.	U.	5·08	−91	+900	6	15	− 62		+ 6	+7 183	11 601	18 852	7 251
10	20	1·3	W.	U.	5·13	−45	+857	6	15	−146		− 46	+7 007	11 520	18 627	7 107
11	20	1·6	E.	D.	5·29	−17	+755	6	22	−150	−6 870	− 80		11 572	18 512	6 940
12	20	1·9	W.	D.	5·42	− 9	+748	6	22	−266	−6 963	−272		11 364	18 321	6 957
13	20	2·2	E.	D.	5·57	−54	+758	6	22	−162	−7 073	−329		11 323	18 229	6 906
14	20	2·6	W.	D.	5·74	−40	+752	6	22	−326	−6 987	−468		11 253	18 098	6 845
15	20	3·0	E.	U.	5·95	−36	+530	6	15	−234		−175	+6 770	11 114	17 943	6 829
16	20	3·4	W.	U.	6·01	−60	+550	7	15	−201		−163	+6 543	11 142	17 723	6 581
17	24	1·7	W.	U.	15·19	−28	+512	8	13	− 4	−3 613	− 7		5 719	9 329	3 610
18	24	2·3	E.	U.	16·11	−18	+669	7	12	+ 7	−3 277	0		5 234	8 504	3 270
19	24	2·6	W.	D.	16·90	−24	− 2	8	9	− 75		− 73	+2 953	4 751	7 706	2 955
20	24	3·0	E.	D.	17·32	−41	+ 14	7	9	−241		−201	+2 717	4 585	7 342	2 757
21	24	3·4	W.	D.	17·68	−45	+ 21	7	9	−541		−477	+2 730	4 288	7 082	2 794
22	24	3·7	E.	D.	17·97	−59	+ 22	8	9	−566		−523	+2 620	4 249	6 912	2 663
23	24	4·0	W.	U.	18·26	−16	+694	8	10	− 39	−2 460	− 9		4 031	6 521	2 490
24	24	4·3	E.	U.	18·38	+35	+510	7	10	+ 29	−2 413	+ 46		4 014	6 444	2 430
25	25	1·0	W.	U.	15·09	−11	+160	7	13	+507	−3 630	+478		5 879	9 480	3 601
26	25	1·2	E.	U.	15·66	+ 6	+146	7	13	+ 69	−3 553	+ 44		5 521	9 049	3 528
27	25	1·7	W.	D.	16·34	+ 6	−566	8	10	−203		− 62	+3 117	5 089	8 347	3 258
28	25	2·0	E.	D.	16·91	+ 9	−395	7	9	+191		+333	+2 977	4 658	7 777	3 119
29	25	2·3	W.	D.	17·46	−18	−381	7	9	− 63		+ 52	+2 720	4 391	7 226	2 835
30	25	2·6	E.	D.	17·87	+ 1	−399	7	9	−245		−127	+2 603	4 210	6 931	2 721
31	25	2·9	W.	U.	18·39	+13	−645	7	11	+271	−2 520	+230		3 972	6 451	2 479
32	25	3·2	E.	U.	18·61	−24	−608	−7	+11 000	+ 66	−2 430	+ 24		− 3 857	− 6 245	+2 388
			Mean t_o=		14·81								Mean	− 5 996	− 9 719	+3 723

* To turn the apparatus end for end would have exposed it to the direct action of the sun. The spring measures were all made during *rising* temperature.

DETERMINATION OF THE COEFFICIENTS OF EXPANSION OF THE STEEL AND BRASS RODS FROM PRECEDING OBSERVATIONS.

Let l = length of 10 rods (steel or brass) at temperature t;
l_0 = average length of same at the average temperature t_0;

hence the conditional equation, $o = l_0 - l + a\ (t - t_0)$.

Substituting the proper values from the preceding table, we get 32 observation equations, viz:

For the steel rods.	For the brass rods.
$o = -2\ 612 + 4{\cdot}56\,a$	$o = -4\ 195 + 4{\cdot}56\,a$
$o = -3\ 202 + 5{\cdot}68\,a$	$o = -5\ 211 + 5{\cdot}68\,a$
$o = -3\ 691 + 6{\cdot}36\,a$	$o = -5\ 889 + 6{\cdot}36\,a$
etc.	etc.

The normal equations are—

for steel, $o = -567\ 884{\cdot}58 + 984{\cdot}103\ 9\,a$, and for brass, $o = -907\ 901{\cdot}66 + 984{\cdot}103\ 9\,a$

hence $a_s = 577{\cdot}057\ 54$ and dividing by 50, the coefficient of expansion $\alpha_s = 11{\cdot}541\ 15$ μ per metre
$a_b = 922{\cdot}566\ 87$ and dividing by 50, the coefficient of expansion $\alpha_b = 18{\cdot}451\ 34$ per metre

also the ratio $\frac{\alpha_b}{\alpha_s} = 1{\cdot}598\ 74$.

The final results are, therefore—

Length of 10 steel rods at $14^\circ{\cdot}81$ C. $= 50m - 5\ 996\mu$
1 steel rod $= 5m - 599{\cdot}6\mu$, i. e., the average of rods of bars 15 and 16
Length of 10 brass rods at $14^\circ{\cdot}81$ C. $= 50m - 9\ 719\mu$
1 brass rod $= 5m - 971{\cdot}9\mu$

Since in all measures with the bars they occur always in pairs, it is not necessary to know the length of the 5-metre components separately for bars 15 and 16. They are, however, of very nearly equal length.

If t = temperature at which the (average) steel and brass rods are of equal length, we find $t = +\ 25^\circ{\cdot}585\ 4$ C.,* and the corresponding length of rods of bars Nos. 15 and 16 = $10m + 44{\cdot}406\mu$, or that of the average bar $5m + 22{\cdot}203\mu$.

Computation of probable errors of the preceding results.

By means of—

$$r_o = 0{\cdot}674\ 5\sqrt{\frac{[pvv]}{[p]\ (n-1)}}$$

we find—

Probable error of resulting value of a for steel $0{\cdot}674\ 5\sqrt{\frac{47\ 681}{148{\cdot}69 \times 31}} = \pm 2{\cdot}17$;

hence of α_s $\pm 0{\cdot}043\ 4\mu$ per metre

Probable error of resulting value of a for brass $0{\cdot}674\ 5\sqrt{\frac{46\ 157}{148{\cdot}69 \times 31}} = \pm 2{\cdot}13$;

hence of α_b $\pm 0{\cdot}042\ 6\mu$ per metre

and $\alpha_s = 11{\cdot}541\ 2 \times 10^{-6}$
$\pm 43\ 4$

and $\alpha_b = 18{\cdot}451\ 3 \times 10^{-6}$
$\pm 42\ 6$

* For this 10 measures in April and May gave $+ 25^\circ{\cdot}30$ C.

For the probable error of the length of an average steel rod we have—

$$0{\cdot}674\,5\sqrt{\frac{[vv]}{n\,(n-1)}} = 0{\cdot}674\,5\sqrt{\frac{113\,200}{992}} = \pm 7{\cdot}21 \text{ for 10 rods; hence for 1 rod } \pm 0{\cdot}72\mu;$$

$$\text{also for brass } 0{\cdot}674\,5\sqrt{\frac{117\,000}{992}} = \pm 7{\cdot}32 \text{ for 10 rods; hence for 1 rod } \pm 0{\cdot}73\mu$$

and finally

Length of an (average) steel rod at temperature t equal $5m - \underset{\pm\ 0{\cdot}7}{599{\cdot}6\mu} + \underset{\pm\ {\cdot}22}{57{\cdot}71\mu}\ (t - 14{\cdot}81)$

Length of an (average) brass rod at temperature t equal $5m - \underset{\pm\ 0{\cdot}7}{971{\cdot}9\mu} + \underset{\pm\ {\cdot}21}{92{\cdot}26\mu}\ (t - 14{\cdot}81)$

THE DUPLEX APPARATUS PROPER.

Determination of length of the steel (or brass) rods as a function of the difference in length of the steel and brass rods when at the same temperature.

By the preceding table of results over the test line we have given 32 differences in length between the two components, together with the corresponding lengths of the steel, as well as of the brass rods. The former will be used. Let $10l$ = length of 10 rods (steel) when the developed differential length of the two components is λ, in the sense $(s - b)$, also $10l_0$ and λ_0 similar quantities at their mean value or $10l_0 = 50m - 5\ 996\mu$ and $\lambda_0 = 3\ 723\mu$; then the 32 conditional equations will be of the form $o = 10\,(l_0 - l) + c\,(\lambda_0 - \lambda)$ from which the coefficient c will have to be determined.

The equations are—

$$o = -2\,612 + 1\,583\,c$$
$$o = -3\,202 + 2\,009\,c$$
$$o = -3\,691 + 2\,198\,c$$
etc.

The normal equation is $o = -196\,145\,716 + 117\,622\,895c$; hence $c = +1{\cdot}667\,58$*

and the probable error of $c = 0{\cdot}674\,5\sqrt{\frac{[pvv]}{[p]\,(n-1)}} = 0{\cdot}674\,5\sqrt{\frac{3{\cdot}547\,5}{503 \times 31}} = \pm 0{\cdot}010\,17.$

For a developed difference of length λ the length of the 10 steel rods is given by

$$10l = 50m - 5\,996\mu + 1{\cdot}667\,6\,(3\,723 - \lambda).$$

For the steel and brass components to be of equal length l_e we have for $\lambda = o$

$$10l_e = 50m + 212\mu,$$

or two bars when components are of equal length $= 10m + 42{\cdot}4\mu$ and 1 bar $l_e = 5m + 21{\cdot}2\mu$.

The probable error of $10l$ is

$$0{\cdot}674\,5\sqrt{\frac{714\,072}{32 \times 31}} = \pm 18{\cdot}1\mu; \text{ hence}$$

$10l$ or 10 steel rods $= 50m - \underset{\pm\ 18}{5\,996\mu} + \underset{\pm\ 10\,2}{1{\cdot}667\,6}\ (3\,723 - \lambda)$

and 1 steel rod $= 5m - \underset{\pm\ 1{\cdot}8}{599{\cdot}6\mu} + \underset{\pm\ 10\,2}{1{\cdot}667\,6\mu}\ (372{\cdot}3 - \lambda)$

where λ refers to one rod, and when components are of equal length

2 rods $= 10m \pm 3{\cdot}6\mu + 42{\cdot}4\mu \pm 7{\cdot}6\mu = 10m + 42{\cdot}4\mu \pm 8{\cdot}4\mu$, and 1 rod $= 5m + \underset{\pm\ 4{\cdot}2}{21{\cdot}2\mu}$.

*For this 10 measures of the test line in April and May gave 1·656 5.

COMPUTATION OF THE LENGTH OF THE BASE.

In the application of the Duplex apparatus to the measure of a base line each subdivision, in the present case each kilometre, is measured independently, and the result will depend upon the accumulated *difference* of length between the two rods of steel and brass; thus it may be likened to a Borda Scale, of which the component metals extend over the whole length of the section. At the same time it is apparent that we can also deduce the length of the base without resort to this principle by simply regarding the apparatus as an ordinary contact-slide apparatus, provided the thermometers between the rods are read during the measure. Since the apparatus contains two rods (steel and brass), we have the means of deducing two separate results. None of these three results is independent of the others, except as to the accidental errors special to each method and developed during the measure.

There are 11 subdivisions of the base, 10 of which are each 1 kilometre and the eleventh 1·2 kilometre in length, of which the first part, 700 metres, was measured at the close of the whole work to take the place of an initial measure when the party was insufficiently experienced. At the southeast end of the base the bar measures commenced 1·141 06 metre past the monument, and at the northwest end they terminated 0·772 54 metre before coming to the monument. The base was measured forward and backward, and the discrepancy shown for each subdivision furnished the data for the computation of the probable error. The "face" of bars for the second half of each kilometre was reversed from that employed during the first half.

(*a*) *Length of base and subdivisions by the thermometric method.*

FIRST MEASURE.

Section.	Date, 1896.	Mean temperature of rods from 6 thermometers.	Rising, falling, or stationary temperature.	Length of section by— Steel rods.		Length of section by— Brass rods.	Correction for inclination.	Shifting forward or backward of— Steel rod.	Shifting forward or backward of— Brass rod.	Length of section from— Steel rods.	Length of section from— Brass rods.	Difference. S.–B.
		°		*m.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*m.*	*m.*	*mm.*
XIa	Oct. 3	21·500	r.	700−	29·90	− 49·66	−23·03	−187·63	−168·74	699·759 44	699·758 57	+0·87
XIb	Sept. 4, 5	27·374	f.	500+	12·53	+ 18·71	25·08	+ 48·12	+ 41·48	500·035 57	500·035 11	+0·46
X	5, 7	29·696	s., r.	1 000+	51·86	+ 80·27	102·77	−228·81	−256·33	999·720 28	999·721 17	−0·89
IX	7, 8	25·239	f., s.	+	0·43	+ 1·97	132·12	+ 38·31	+ 41·07	·906 62	·906 98	−0·36
VIII	8, 9	18·095	f., r.	−	82·01	−133·77	70·70	+ 53·16	−104·09	·900 45	·899 62	+0·83
VII	10	16·512	r., s.	−	100·28	−162·98	40·59	+ 70·43	+133·60	·929 56	·930 03	−0·47
VI	11	23·531	r., s.	−	19·28	− 33·48	76·77	+ 76·40	+ 90·41	·980 35	·980 16	+0·19
V	12	25·997	r., s.	+	9·18	+ 12·02	62·19	− 18·33	− 20·88	·928 66	·928 95	−0·29
IV	14	29·109	r., s.	+	45·09	+ 69·44	38·44	− 7·59	− 31·93	·999 06	·999 07	−0·01
III	15	28·910	r., s.	+	42·79	+ 65·77	44·41	− 24·64	− 47·34	·973 74	·974 02	−0·28
II	16	22·974	r., f.	−	25·71	− 43·75	78·93	+ 30·86	+ 49·00	·926 22	·926 32	−0·10
I	17	20·805	r., f.	−	50·74	− 83·77	−40·65	+ 66·88	+ 99·95	·975 49	·975 53	−0·04
									Σ	11 199·035 44	11 199·035 53	−0·09

(*a*) *Length of base and subdivisions by the thermometric method*—Completed.

SECOND MEASURE.

Section.	Date, 1896.	Mean temperature of rods from 6 thermometers.	Rising, falling, or stationary temperature.	Length of section by— Steel rods.		Length of section by— Brass rods.	Correction for inclination.	Shifting forward or backward of— Steel rod.	Shifting forward or backward of— Brass rod.	Length of section from— Steel rods.	Length of section from— Brass rods.	Difference. S.-B.
		°		*m.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*m.*	*m.*	*mm.*
I	Sept. 18	23·294	r., f.	1 000	− 22·01	− 37·85	−37·11	+ 37·34	+ 53·23	999·978 22	999·978 27	−0·05
II	22	20·578	s., f.		− 53·36	− 87·96	−90·22	+ 70·52	+105·07	·926 94	·926 89	+0·05
III	23	20.721	r., s.		− 51·71	− 85·32	−21·56	+ 48·72	+ 82·31	·975 45	·975 43	+0·02
IV	24	18·385	r., s.		− 78·66	−128·42	− 9·90	+ 89·21	+139·22	1 000·000 65	1 000·000 90	0·25
V	25	17·349	r., s.		− 90·62	−147·54	−10·89	+ 30·98	+ 88·31	999·929 47	999·929 88	−0·41
VI	26	17·587	r., s.		− 87·87	−143·14	−21·97	+ 89·28	+145·55	·979 44	·980 44	−1·00
VII	28	20·660	r., s.		− 52·41	− 86·45	−15·05	− 2·07	+ 32·43	·930 47	·930 93	−0·46
VIII	29	22·468	r., s.		− 31·55	− 53·09	−21·00	− 48·72	− 26·73	·898 73	·899 18	−0·45
IX	30	22·658	r., s.		− 29·35	− 49·58	−49·04	− 14·30	+ 6·01	·907 31	·907 39	−0·08
X	Oct. 1	23·494	r., s.		− 19·71	− 34·16	−27·89	−229·32	−214·94	·723 08	·723 01	+0·07
XI	1, 2	24·301	f., r., r.	1 200	− 12·47	− 23·13	−41·22	−148·43	−138·14	1 199·797 88	1 199·797 51	+0·37
									Σ	11 199·047 64	11 199·049 83	−2·19

The last column shows a remarkable accord between the results by the two metallic rods.

(*b*) *Length of base and subdivisions by the duplex method.*

FIRST AND SECOND MEASURES.

The third and fourth columns in the table below contain the differences accumulated during each section by the two rods, and the values are taken from the preceding table, column (9) minus column (8); the corrections for inclination are the same as before.

No. of section.	No. of bars.	Accumulated differences in total length. First measure.	Accumulated differences in total length. Second measure.	Length of mean rod (steel) 5 metres, First measure.	Length of mean rod (steel) 5 metres, Second measure.	Length of section from— First measure.	Length of section from— Second measure.	Difference first–second measure.
		mm.	*mm.*	*μ*	*μ*	*m.*	*m.*	*mm.*
XIa	140	+18·89	+10·29	−203·76	− 50·26	1 199·797 05	1 199·798 29	−1·24
XIb	100	− 6·64		+132·31				
X	200	−27·52	+14·38	+250·71	− 98·65	999·718 56	999·723 06	−4·50
IX	200	+ 2·76	+20·31	− 1·77	−148·10	·905 84	·907 04	−1·20
VIII	200	+50·93	+21·19	−403·41	−162·11	·901 78	·897 86	+3·92
VII	200	+63·17	+34·50	−505·46	−266·41	·928 75	·929 60	−0·85
VI	200	+14·01	+56·27	− 95·57	−447·93	·980 52	·977 72	+2·80
V	200	− 2·55	+57·33	+ 42·51	−456·77	·927 98	·928 74	−0·76
IV	200	−24·34	+50·01	+224·19	−395·74	·998 81	1 000·000 16	−1·35
III	200	−22·70	+33·59	+210·52	−258·83	·973 05	999·975 39	−2·34
II	200	+18·14	+34·55	−130·00	−266·83	·925 93	·926 93	−1·00
I	200	+33·07	+15·89	−254·49	−111·24	·975 33	·977 98	−2·65
					Σ	11 199·033 60	11 199·042 77	−9·17

(*b*) *Length of base and subdivisions by the duplex method*—Completed.

RECAPITULATION OF RESULTS FOR LENGTH OF BASE.

[1·913 60 metres has been added to preceding results to refer the measure to the monuments.]

	First measure.	Second measure.	Mean.	Probable error of measurement.	
	m.	*m.*	*m.*	*mm.*	
From steel rods using coefficient of expansion.	11 200·949 0	11 200·961 2	11 200·955 1	±2·0	$\pm\frac{1}{5\ 500\ 000}$ part.
From brass rods using coefficient of expansion.	·949 1	·963 4	·956 3	±2·0	$\pm\frac{1}{5\ 700\ 000}$ part.
From difference in length of rods, over total line.	·947 2	·956 4	·951 8	±2·7	$\pm\frac{1}{4\ 200\ 000}$ part.
		Mean	11 200·954 4		

Where the probable error, in each case, rests upon the differences Δ of the 11 sections, between the forward and backward measures and is given by $\frac{0·674}{2}\,(\Sigma\Delta^2)^{\frac{1}{2}}$

It would appear from the probable errors, as found at this base, that the duplex contact-slide apparatus has no special advantage over the ordinary contact-slide steel rod with thermometric readings. While the duplex apparatus demands considerably more labor for standardization, record, and computation, it possesses the unique feature of being independent of thermometers and produces results vying in accuracy with the best.

There remain for consideration three sources of minute effects upon the length of the base, viz: the push of the contact-slide spring at the time of contact, the change in length of bars due to wear of the knife-edge, and the change in position of the rod relative to the point of support of the metallic casing *during* the time of laying a bar.

Respecting the first source actual trials indicated that the pressure of the springs of about 2¼ ounces produced a displacement, due to elastic yielding of the cradles sustaining the bars of 4½ microns, the bars being at an average height in the cradles and trestles. The effect on the base length would be about 10 millimetres, subtractive from the measured length.

As to the second source of error, measures taken at the close of the work (December 15, 1896) indicated by the increased width of the knife-edges that a considerable amount of agate, estimated at 9 microns per bar, had worn away; if we take one-half of this as representing the average value, the whole effect on the length would be 2 240 × 4·5 or about + 10 millimetres.

The last-mentioned source of error depends upon the rate of change of temperature and the rapidity of the base measure, which latter was, on the average, 40 bars laid in 60 minutes. The interval of time between making and breaking contact was about one minute, during which short time no appreciable change in the effective length of the rods could have taken place. This effective length lies mostly between the rear or knife-edge trestle and the forward end of the bar, about 3⅔ metres. The effect on the length of the base changes sign with change from rising to falling temperature and is therefore to some extent compensatory.

For the determination of the height of the base line above the sea level, we must for the present depend upon the results of the zenith distances measured at the triangulation

stations in the Rocky Mountain region between Pikes Peak and the Sierra Nevada. The heights of the stations as adjusted depend upon Pikes Peak, 4 300·2 metres, Round Top, 3 165·6 metres, and Mount Lola, 2 786·8 metres, the adjusted height of Salt Lake Southeast Base being 1 289·4 metres.

A line of spirit levels was run forward and backward by J. H. Turner in October and November, 1888, from the crossing of the Union Pacific and Utah Central railroads at Ogden (of the same elevation as the old passenger station at Ogden) to the United States Engineers' astronomic observatory; thence to the Hooper bench mark on the shore of the Great Salt Lake, about 16 kilometres or 10 miles in a southwesterly direction from Ogden. From the Hooper bench mark levels were run to Salt Lake Northwest Base, a distance of 7·2 kilometres or 4½ miles, and thence over the length of the base, a distance of 11·2 kilometres, or 7 miles, by J. J. Gilbert in August and October, 1896. The resulting heights based on the height of Salt Lake Southeast Base are as follows:

	Metres.	Feet.
Southeast Base, top of bolt and surface stone	1 289·40	
Northwest Base, top of bolt and surface stone	1 294·89	
First kilometre stone from Southeast Base	1 291·57	
Second kilometre stone	1 293·77	
Third kilometre stone	1 295·37	
Fourth kilometre stone	1 296·73	
Fifth kilometre stone	1 297·18	
Sixth kilometre stone	1 298·39	
Seventh kilometre stone	1 298·65	
Eighth kilometre stone	1 298·01	
Ninth kilometre stone	1 297·08	
Tenth kilometre stone	1 296·52	
Hooper bench mark, bowlder on lake shore	1 288·71=	4 228·0
United States Engineers' observatory, top of transit pier	1 338·12=*	4 390·1
Top of rail at crossing of Union Pacific and Utah Central railroads or old passenger station at Ogden	1 315·07=†	4 314·5

The average height of the base (stubs) above Southeast Base is 6·5 metres and average height of the base bars above the stubs 0·9 metre. Hence average height of base bars above mean sea level is 1 296·8 metres. For the reduction to sea level s (reduced) = 11 198·7 metres, $h = 1\ 296{\cdot}8$ metres and $\log \rho = 6{\cdot}804\ 58$; hence reduction $= \frac{hs}{\rho} = -2{\cdot}277\ 5$ metres. Measured length of base, 11 200·954 4 metres. Length of base reduced to sea level, 11 198·676 9 metres.

*Lieutenant Wheeler gives the height of the transit pier as 4 374·0 feet, in his report on Surveys West of the One-hundredth Meridian.

†In Bulletin No. 76 of the United States Geological Survey the height of this crossing is stated to be 4 303 feet. Mr. W. G. Curtis, engineer of the Southern Pacific Railroad, in his letter of December 29, 1896, gives the elevation of bottom of ties above mean *low* water in San Francisco Bay as 4 296·14 feet, corresponding to an elevation of 4 293·3 feet of top of rail above half tide level.

PROBABLE ERROR OF THE LENGTH OF THE SALT LAKE BASE LINE.

The probable error of measurement may be taken as not more than $\frac{1}{4\ 500\ 000}$ part of the length or $\pm 2{\cdot}5$ millimetres.

The error due to standardization of the base bars, whether we make use of the steel or the brass rods, is found from the expression for the length of an average steel rod

$$5m - \underset{\pm 0{\cdot}7}{599{\cdot}6\,\mu} + \underset{\pm 0{\cdot}22}{57{\cdot}71\,\mu}\,(t - 14^\circ{\cdot}81)$$

the number of bars is 2 240. The mean temperature of the base measures is $22^\circ{\cdot}66$C.; hence the probable errors $\pm 1{\cdot}6$ millimetres and $\pm 3{\cdot}9$ millimetres.

The probable error of the length of the 5-metre bar-in-ice No. 17 is $\pm 1{\cdot}1\,\mu$, the corresponding uncertainty of the base being $1{\cdot}1 \times 2\ 240 = \pm 2{\cdot}5$ millimetres.

The uncertainty in the elevation is estimated at 2½ metres; hence probable error in reduction to sea level $= \pm 4{\cdot}4$ millimetres. Combining these five quantities we get for the total probable error

$$\sqrt{(2{\cdot}5)^2 + (1{\cdot}6)^2 + (3{\cdot}9)^2 + (2{\cdot}5)^2 + (4{\cdot}4)^2} = \pm 7 \text{ millimetres}$$

or $\frac{1}{1\ 600\ 000}$ part of the length.

Length of base 11 198·677*m* ± 0·007*m*.
and its logarithm 4·049 166 72
± 27

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE SALT LAKE BASE NET, 1887–88–89, 1891–92, 1896–97.

Salt Lake Northwest Base, Davis County, Utah. August 6 to August 14, 1896. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
1	Antelope	0	00	00·000	±·081	+·104	00·104	−·067	00·037
2	Promontory	100	51	17·201	·092	−·122	17·079	+·125	17·204
3	Ogden Peak	214	31	36·342	·080	+·148	36·490	−·024	36·466
4	Salt Lake Southeast Base	287	34	49·556	·092	−·080	49·476	−·034	49·442

Probable error of a single observation of a direction (*D.* and *R.*) $- \pm 0''{\cdot}59$.

Salt Lake Southeast Base, Davis County, Utah. July 17 to July 26, 1896. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
5	Antelope	0	00	00·000	±·091	+·101	00·101	+·151	00·252
6	Salt Lake Northwest Base	72	39	13·222	·106	−·080	13·142	+·065	13·207
7	Ogden Peak	149	25	04·832	·076	+·165	04·997	−·441	04·556
8	Waddoup	259	37	17·050	·113	−·079	16·971	+·225	17·196

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''{\cdot}65$.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE SALT LAKE BASE NET, 1887–88–89, 1891–92, 1896–97—continued.

Waddoup, Davis County, Utah. May 25 to June 18, 1892, and June 25 to July 3, 1896. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment. °	′	″	Approximate probable error. ″	Reduction to sea level. ″	Resulting seconds. ″	Corrections from base-net adjustment. ″	Final seconds in triangulation. ″
	Azimuth Mark.	0	00	00·000	± ·106				
9	Deseret	82	31	23·634	·112	+ ·205	23·839	+ ·843	24·682
10	Antelope	133	18	49·657	·072	− ·053	49·604	− ·008	49·596
11	Promontory	165	03	25·477	·081	− ·127	25·350	− ·066	25·284
12	Salt Lake Southeast Base	173	33	24·056	·150	− ·077	23·979	− ·201	23·778
13	Ogden Peak	211	28	26·908	·083	+ ·005	26·913	− ·568	26·345

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·88.

Ogden Peak, Weber County, Utah. September 11 to October 10, 1888. 50-centimetre theodolite, No. 5. W. Eimbeck, observer. June 24 to June 30, 1891. 50-centimetre theodolite, No. 5. P. A. Welker, observer. (W. Eimbeck, chief of party.) July 16 to July 29, 1896. 30-centimetre theodolite, No. 146. P. A. Welker, observer. (W. Eimbeck, chief of party.)

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
	Azimuth Mark (North Ogden)	0	00	00·000	± ·052*	− ·118	59·882		
	Draper	193	54	09·172	·105†	− ·037	09·135		
14	Mount Nebo	196	16	31·242	·077†	− ·029	31·213	− ·378	30·835
	City Creek	199	49	48·631	·061*	·000	48·631		
15	Waddoup	200	39	53·835	·080‡	+ ·002	53·837	+ ·790	54·627
	Oquirrh	221	37	00·243	·085†	+ ·121	00·364		
16	Salt Lake SE. Base	232	32	39·895	·089‡	+ ·072	39·967	+ ·382	40·349
17	Deseret	237	33	22·988	·089†	+ ·202	23·190	− ·787	22·403
18	Antelope	246	47	32·372	{·071† ·061‡}	+ ·124	32·496	+ ·292	32·788
19	Ibepah	249	12	02·091	·062†	+ ·227	02·318	− ·729	01·589
20	Salt Lake NW. Base	262	43	36·280	·074‡	+ ·065	36·345	+ ·269	36·614
21	Pilot Peak	284	31	30·171	·086†	+ ·038	30·209	− ·274	29·935
	Azimuth Station	303	10	15·488		− ·037	15·451		
22	Promontory	303	42	05·866	·078‡	− ·058	05·808	+ ·434	06·242

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·66.

*1888 and 1891. †1888. ‡1896.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE SALT LAKE BASE NET, 1887-88-89, 1891-92, 1896-97—continued.

Deseret, Tooele County, Utah. September 1 to September 13, 1887. 50-centimetre theodolite, No. 5. W. Eimbeck, observer. September 4 to September 18, 1892. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Azimuth Mark, 1892	0	00	00 ·000	±....				
23	Promontory	7	07	51 ·114	·072	+ ·046	51 ·160	— ·688	50 ·472
24	Antelope	28	19	46 ·672	·084	+ ·114	46 ·786	+ ·210	46 ·996
25	Ogden Peak	33	44	00 ·630	·071	+ ·178	00 ·808	— ·143	00 ·665
26	Waddoup	47	53	36 ·612	·093	+ ·081	36 ·693	— ·343	36 ·349
	Oquirrh	61	44	39 ·673	·079	+ ·195	39 ·868		
	Draper	81	28	05 ·028	·102	+ ·045	05 ·073		
27	Mount Nebo	130	50	51 ·549	·105	— ·231	51 ·318	+ ·189	51 ·507
28	Ibepah	234	34	20 ·513	·085	+ ·211	20 ·724	+ ·599	21 ·323
29	Pilot Peak	294	03	12 ·415	·102	— ·170	12 ·245	+ ·177	12 ·422
	Onaqui, 1887	359	59	59 ·342		+ ·029	59 ·371		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·68.

Ibepah, Juab County, Utah. August 23 to September 27, 1889. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00 ·000	± ·045				
30	Ogden Peak	25	43	47 ·159	·092	+ ·187	47 ·346	+ ·013	47 ·359
31	Deseret	34	55	41 ·025	·089	+ ·200	41 ·225	— ·192	41 ·033
32	Mount Nebo	67	43	04 ·124	·071	+ ·001	04 ·125	+ ·097	04 ·222
	Tushar	117	31	04 ·280	·077	— ·237	04 ·043		
	Wheeler Peak	177	52	34 ·545	·088	+ ·166	34 ·711		
	Diamond Peak	238	59	34 ·992	·082	+ ·064	35 ·056		
33	Pilot Peak	332	05	10 ·271	·086	— ·042	10 ·229	+ ·082	10 ·311

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·62.

Mount Nebo, Juab County, Utah. June 16 to July 29, 1887. 50-centimetre thoedolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00 ·000	± ·046				
	Patmos Head	99	26	42 ·277	·096	— ·096	42 ·181		
	Wasatch	155	13	16 ·508	·091	— ·137	16 ·371		
	Tushar	194	36	40 ·046	·090	+ ·155	40 ·201		
	Scipio	213	51	58 ·848	....	+ ·188	59 ·036		
	Wheeler Peak	242	40	45 ·694	·075	+ ·178	45 ·872		
34	Ibepah	265	48	49 ·527	·080	— ·011	49 ·516	— ·147	49 ·369
35	Pilot Peak	299	41	13 ·102	·070	— ·199	12 ·903	— ·051	12 ·852
36	Deseret	309	18	29 ·821	·112	— ·219	29 ·602	— ·133	29 ·469
	Onaqui	315	22	52 ·056	·070	— ·176	51 ·880		
	Oquirrh	332	45	19 ·604	·066	— ·125	19 ·479		
37	Ogden Peak	350	55	13 ·527	·063	— ·024	13 ·403	+ ·330	13 ·833
	Draper	353	14	45 ·190	·097	— ·008	45 ·182		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·61.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED AT THE STATIONS FORMING THE SALT LAKE BASE NET, 1887–88–89, 1891–92, 1896–97—completed.

Antelope, Davis County, Utah. October 4 to October 23, 1892. 50-centimeter theodolite, No. 5. W. Eimbeck and P. A. Welker, observers. June 25 to July 4, 1896. 30-centimetre theodolite No. 146. P. A. Welker, observer. (W. Eimbeck, chief of party.)

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
44	Ogden Peak	0	00	00 ·000	± ·083	+ ·182	00 ·182	− ·277	59 ·905
45	Salt Lake SE. Base	16	20	03 ·815	·094	+ ·065	03 ·880	− ·206	03 ·674
46	Waddoup	55	42	47 ·371	·079	− ·034	47 ·337	− ·048	47 ·289
47	Deseret	165	21	37 ·057	·123	+ ·189	37 ·246	+ ·234	37 ·480
48	Pilot Peak	226	23	06 ·225	·138	− ·021	06 ·204	− ·343	05 ·861
49	Promontory	288	47	49 ·415	·107	− ·095	49 ·320	+ ·383	49 ·703
	Azimuth Mark	302	00	46 ·574	·151				
50	Salt Lake NW. Base	341	24	26 ·394	·086	+ ·067	26 ·461	+ ·258	26 ·719

Probable error of a single observation of a direction ($D.$ and $R.$) = ± 1″·02.

Pilot Peak, Elko County, Nevada. July 5 to July 22, 1889. 50-centimetre theodolite, No. 5. W. Eimbeck, observer. August 7 to August 18, 1892. 50-centimetre theodolite, No. 5. P. A. Welker, observer. (W. Eimbeck, chief of party.) August 6 to August 17, 1897. 50-centimetre theodolite, No. 5. P. A. Welker, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
	Azimuth Mark, 1889	0	00	00 ·000	±0 ·049				
	Reference Mark, 1892 and 1897	0	00	02 ·534	·055*				
	Cache	2	19	22 ·749	·089*				
	Oxford	36	43	40 ·495	·151*				
38	Promontory	64	26	05 ·747	·065*	+ ·055	05 ·802	+ ·198	06 ·000
39	Ogden Peak	70	34	24 ·955	{·066 / ·064*}	+ ·043	24 ·998	− ·145	24 ·853
40	Antelope	79	13	44 ·735	·074	− ·008	44 ·727	+ ·038	44 ·765
41	Deseret	103	56	04 ·921	·054	− ·169	04 ·752	− ·082	04 ·670
42	Mount Nebo	111	06	37 ·692	·069	− ·210	37 ·482	+ ·021	37 ·503
43	Ibepah	161	37	22 ·197	·069	− ·047	22 ·150	− ·030	22 ·120
	Wheeler Peak	172	37	22 ·903	·075	+ ·045	22 ·948		

Probable error of a single observation of a direction ($D.$ and $R.$) = ± 0″·80.

Promontory, Boxelder County, Utah. July 3 to July 18, 1892. 50-centimetre theodolite, No. 5. W. Eimbeck, observer. August 7 to August 13, 1896 30-centimetre theodolite, No. 146. P. A. Welker, observer. (W. Eimbeck, chief of party.)

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00 ·000	± ·112				
51	Ogden Peak	142	33	18 ·287	·077	− ·081	18 ·206	− ·380	17 ·826
52	Salt Lake NW. Base	167	54	30 ·502	·075	− ·078	30 ·424	+ ·183	30 ·607
53	Waddoup	173	06	09 ·217	·063	− ·081	09 ·136	− ·256	08 ·880
54	Antelope	194	26	38 ·562	·062	− ·094	38 ·468	− ·495	37 ·973
55	Deseret	229	48	34 ·243	·117	+ ·075	34 ·318	+ ·615	34 ·933
56	Pilot Peak	297	14	29 ·422	·116	+ ·082	29 ·504	+ ·333	29 ·837

Probable error of a single observation of a direction ($D.$ and $R.$) = ± 0″·57.

* The directions marked by a * depend on the probable error ± ″·054 of Ogden Peak, during the second and third occupations

Respecting weights to the several directions entering into the adjustment, it has been decided to give them all the same—that is, unit weight. This proceeding is justified by the following considerations.

From the approximate probable errors of directions in the preceding abstracts we find the average value from 82 directions $= \pm 0''.088$; on the other hand, we derive from the base figure adjustment, as given in the following pages, the probable error of a direction by using ⅔ of the value resulting from the 56 direction corrections, viz: $\pm 0''.31$, or 3.4 times the first value. We may also use the 99 angular corrections of the 33 triangles, whence we get for the probable error of a direction $\frac{2}{3}\sqrt{\frac{25.0}{2 \times 99}} = \pm 0''.24$. Again, if we operate with the closing errors of the triangles, we find for the probable error of a direction—

$$\frac{2}{3}\sqrt{\frac{37.96}{33 \times 6}} = \pm 0''.30$$

We thus find the probable error of a direction e_t as derived from the corrections demanded by the adjustment of the base net $= \pm 0''.28$ and the same e_s as derived from the station adjustment $= \pm 0''.09$; the fact that e_t is three times as great as e_s is attributed mainly to the effect of local deflections in measuring angles, the vertical axis of the theodolite being necessarily adjusted to the plumb-line. Besides, a very careful adjustment of the instrument is required when the station observed upon is considerably above or below the one occupied. Persistent lateral refraction also has a share in producing the above result. Following the methods outlined at the beginning of this paper and used in the adjustment of the Yolo Base Net, we have $e_c = \sqrt{(0.28)^2 - (0.09)^2} = \pm 0.27$, which is to be combined with the particular value of e_s; hence the relative weight of an observed direction becomes—

$$p = \frac{1}{e^2} = \frac{1}{e_s^2 + (0.27)^2}$$

In the case of the Salt Lake Base Net, we have in the main figure the *extreme* values of $e_s \pm 0''.06$ and $\pm 0''.15$; hence the extreme weights to directions would be in the proportion of 13 to 11 nearly. The introduction of weights was therefore deemed unnecessary, especially when we consider the strength of the development of the length of the base to that of the primary line.

FIGURE ADJUSTMENT.

Observation equations.

No.	
1	$0=+0{\cdot}582+(45)-(50)+(1)-(4)+(6)-(5)$
2	$0=+0{\cdot}610+(45)-(44)+(18)-(16)+(7)-(5)$
3	$0=+0{\cdot}602+(44)-(50)+(1)-(3)+(20)-(18)$
4	$0=-0{\cdot}581+(52)-(51)+(22)-(20)+(3)-(2)$
5	$0=+0{\cdot}733+(13)-(11)+(53)-(51)+(22)-(15)$
6	$0=+0{\cdot}109+(13)-(12)+(8)-(7)+(16)-(15)$
7	$0=-0{\cdot}306+(26)-(23)+(55)-(53)+(11)-(9)$
8	$0=+1{\cdot}123+(26)-(24)+(47)-(46)+(10)-(9)$
9	$0=-1{\cdot}076+(39)-(38)+(56)-(51)+(22)-(21)$
10	$0=-1{\cdot}393+(40)-(38)+(56)-(54)+(49)-(48)$
11	$0=+1{\cdot}427+(41)-(38)+(56)-(55)+(23)-(29)$
12	$0=+0{\cdot}318+(40)-(39)+(21)-(18)+(44)-(48)$
13	$0=+0{\cdot}661+(41)-(40)+(48)-(47)+(24)-(29)$
14	$0=-0{\cdot}009+(36)-(35)+(42)-(41)+(29)-(27)$
15	$0=-0{\cdot}388+(37)-(36)+(27)-(25)+(17)-(14)$
16	$0=-0{\cdot}500+(30)-(33)+(43)-(39)+(21)-(19)$
17	$0=-0{\cdot}060+(32)-(33)+(43)-(42)+(35)-(34)$
18	$0=+0{\cdot}890+(31)-(30)+(19)-(17)+(25)-(28)$
19	$0=-0{\cdot}210+(32)-(30)+(19)-(14)+(37)-(34)$
20	$0=+2{\cdot}23-0{\cdot}67(1)-0{\cdot}64(3)+1{\cdot}31(4)-4{\cdot}67(16)+8{\cdot}29(18)-3{\cdot}62(20)+7{\cdot}18(44)-4{\cdot}16(45)-3{\cdot}02(50)$
21	$0=+2{\cdot}25-0{\cdot}67(1)-0{\cdot}64(3)+1{\cdot}31(4)-2{\cdot}49(10)+5{\cdot}19(12)-2{\cdot}70(13)-3{\cdot}39(15)+7{\cdot}01(16)-3{\cdot}62(20)+5{\cdot}59(45)-2{\cdot}57(46)-3{\cdot}02(50)$
22	$0=-7{\cdot}94-7{\cdot}37(18)+9{\cdot}79(20)-2{\cdot}42(22)-6{\cdot}26(44)-1{\cdot}61(49)+7{\cdot}87(50)-4{\cdot}44(51)+8{\cdot}66(52)-4{\cdot}22(54)$
23	$0=+0{\cdot}06-2{\cdot}96(10)+3{\cdot}40(11)-0{\cdot}44(13(-2{\cdot}02(15)+3{\cdot}39(18)-1{\cdot}37(22)-1{\cdot}65(51)+5{\cdot}39(53)-3{\cdot}74(54)$
24	$0=-2{\cdot}31-1{\cdot}72(9)+5{\cdot}12(10)-3{\cdot}40(11)-5{\cdot}43(23)+11{\cdot}35(24)-5{\cdot}92(26)-5{\cdot}39(53)+8{\cdot}36(54)-2{\cdot}97(55)$
25	$0=-26{\cdot}44-12{\cdot}95(17)+15{\cdot}67(18)-2{\cdot}72(21)+22{\cdot}10(24)-22{\cdot}26(25)+0{\cdot}16(29)-13{\cdot}83(39)+18{\cdot}41(40)-4{\cdot}58(41)$
26	$0=+1{\cdot}92+5{\cdot}43(23)-5{\cdot}59(24)+0{\cdot}16(29)-7{\cdot}97(38)+12{\cdot}55(40)-4{\cdot}58(41)-3{\cdot}45(54)+2{\cdot}97(55)+0{\cdot}48(56)$
27	$0=+5{\cdot}33-1{\cdot}35(18)+2{\cdot}72(21)-1{\cdot}37(22)-7{\cdot}97(38)+13{\cdot}83(39)-5{\cdot}86(40)-1{\cdot}65(51)+1{\cdot}17(54)+0{\cdot}48(56)$
28	$0=+5{\cdot}65-2{\cdot}40(14)+4{\cdot}37(17)-1{\cdot}97(21)-12{\cdot}42(35)+14{\cdot}79(36)-2{\cdot}37(37)-3{\cdot}20(39)+19{\cdot}92(41)-16{\cdot}72(42)$
29	$0=+6{\cdot}26-2{\cdot}40(14)+12{\cdot}62(17)-10{\cdot}22(19)-13{\cdot}00(30)+16{\cdot}27(31)-3{\cdot}27(32)-2{\cdot}22(34)+4{\cdot}59(36)-2{\cdot}37(37)$
30	$0=+4{\cdot}17-2{\cdot}40(14)+4{\cdot}37(17)-1{\cdot}97(21)+4{\cdot}35(31)-3{\cdot}27(32)-1{\cdot}08(33)-2{\cdot}22(34)+4{\cdot}59(36)-2{\cdot}37(37)-3{\cdot}20(39)+4{\cdot}53(41)-1{\cdot}33(43)$

FIGURE ADJUSTMENT—continued.

Correlate equations.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
(1)=	+1		+1											
(2)				−1										
(3)			−1	+1										
(4)	−1													
(5)	−1	−1	...	...	...	...	...	...	...	...	...	...	...	...
(6)	+1													
(7)		+1				−1								
(8)						+1								
(9)							−1	−1						
(10)	...	...	...	...	...	...	...	+1	...	...	...	...	...	...
(11)					−1		+1							
(12)						−1								
(13)					+1	+1								
(14)														
(15)	...	...	...	...	−1	−1	...	...	...	...	...	...	...	...
(16)		−1				+1								
(17)														
(18)		+1	−1									−1		
(19)														
(20)	...	...	+1	−1	...	...	...	...	...	...	...	...	...	...
(21)									−1			+1		
(22)				+1	+1				+1					
(23)							−1				+1			
(24)								−1					+1	
(25)	...	...	...	...	...	...	...	...	...	...	...	...	...	...
(26)							+1	+1						
(27)														−1
(28)														
(29)											−1		−1	+1
(30)	...	...	...	...	...	...	...	...	...	...	...	...	...	...
(31)														
(32)														
(33)														
(34)														
(35)	...	...	...	...	...	...	...	...	...	...	...	...	...	−1
(36)														+1
(37)														
(38)									−1	−1	−1			
(39)									+1			−1		
(40)	...	...	...	...	...	...	...	...	...	+1	...	+1	−1	...
(41)											+1		+1	−1

FIGURE ADJUSTMENT—continued.

Correlate equations—Continued.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
(42)=														+1
(43)														
(44)		−1	+1									+1		
(45)	−1	−1	...	...	...	...	...	...	...	...	...	...	...	...
(46)								−1						
(47)								+1					−1	
(48)										−1		−1	+1	
(49)										+1				
(50)	−1	...	−1	...	...	...	...	...	...	...	...	...	...	...
(51)				−1	−1				−1					
(52)				+1										
(53)					+1		−1							
(54)										−1				
(55)	...	...	...	...	...	...	+1	...	...	...	−1	...	...	...
(56)									+1	+1	+1			

Correlate equations—Continued.

Corrections.	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}
(1)						−0·67	−0·67		
(2)									
(3)						−0·64	−0·64		
(4)						+1·31	+1·31		
(5)	...	...	...	...	...	......	......	......	......
(6)									
(7)									
(8)									
(9)									
(10)	...	...	...	...	...	......	−2·49	......	−2·96
(11)									+3·40
(12)							+5·19		
(13)							−2·70		−0·44
(14)	−1				−1				
(15)	...	...	...	...	...	......	−3·39	......	−2·02
(16)						−4·67	+7·01		
(17)	+1			−1					
(18)						+8·29		−7·37	+3·39
(19)		−1		+1	+1				
(20)	...	...	...	...	...	−3·62	−3·62	+9·79	......
(21)		+1							
(22)								−2·42	−1·37

FIGURE ADJUSTMENT—continued.

Correlate equations—Continued.

Corrections.	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}
(23)									
(24)									
(25)	−1	...	...	+1	...	......	......	......	......
(26)									
(27)	+1								
(28)				−1					
(29)									
(30)	...	+1	...	−1	−1	......	......	......	......
(31)				+1					
(32)			+1		+1				
(33)		−1	−1						
(34)			−1		−1				
(35)	...	...	+1	...	...	......	......	......	......
(36)	−1								
(37)	+1				+1				
(38)									
(39)		−1							
(40)	...	...	...	...	...	......	......	......	......
(41)									
(42)			−1						
(43)		+1	+1						
(44)						+7·18		−6·26	
(45)	...	...	...	...	...	−4·16	+5·59	......	......
(46)							−2·57		
(47)									
(48)									
(49)								−1·61	
(50)	...	...	...	...	...	−3·02	−3·02	+7·87	......
(51)								−4·44	−1·65
(52)								+8·66	
(53)									+5·39
(54)								−4·22	−3·74
(55)	...	...	...	...	...	......	......	......	......
(56)									

FIGURE ADJUSTMENT—continued.

Correlate equations—Continued.

Corrections.	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}
(1)							
(2)							
(3)							
(4)							
(5)	....	....	....	....	....	....	....
(6)							
(7)							
(8)							
(9)	− 1·72						
(10)	+ 5·12	....	....	....	....	....	....
(11)	− 3·40						
(12)							
(13)							
(14)					− 2·40	− 2·40	− 2·40
(15)	....	....	....	....	....	....	....
(16)							
(17)		−12·95			+ 4·37	+12·62	+ 4·37
(18)		+15·67		− 1·35			
(19)						−10·22	
(20)	....	....	....	....	....	....	....
(21)		− 2·72		+ 2·72	− 1·97		− 1·97
(22)				− 1·37			
(23)	− 5·43		+ 5·43				
(24)	+11·35	+22·10	− 5·59				
(25)	....	−22·26	....	....	....	....	....
(26)	− 5·92						
(27)							
(28)							
(29)		+ 0·16	+ 0·16				
(30)	....	....	....	....	....	−13·00	....
(31)						+16·27	+ 4·35
(32)						− 3·27	− 3·27
(33)							− 1·08
(34)						− 2·22	− 2·22
(35)	....	....	....	....	−12·42	....	....
(36)					+14·79	+ 4·59	+ 4·59
(37)					− 2·37	− 2·37	− 2·37
(38)			− 7·97	− 7·97			
(39)		−13·83		+13·83	− 3·20		− 3·20
(40)	....	+18·41	+12·55	− 5·86	....	....	....
(41)		− 4·58	− 4·58		+19·92		+ 4·53

FIGURE ADJUSTMENT—continued.

Correlate equations—Completed.

Corrections.	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}
(42)					16·72		
(43)							− 1·33
(44)							
(45)	....	....	....	....	....	....	....
(46)							
(47)							
(48)							
(49)							
(50)	....	....	....	....	....	....	....
(51)				− 1·65			
(52)							
(53)	− 5·39						
(54)	+ 8·36		− 3·45	+ 1·17			
(55)	− 2·97	....	+ 2·97	....	....	....	....
(56)			+ 0·48	+ 0·48			

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
0 = +0·582	+6	+2	+2											
+0·610		+6	−2			−2						−2		
+0·602			+6	−2								+2		
−0·581				+6	+2				+2					
+0·733	...	...	...	...	+6	+2	−2	...	+2	...	...	...	...	...
+0·109						+6								
−0·306							+6	+2			−2			
+1·123								+6					−2	
−1·076									+6	+2	+2	−2		
−1·393	...	...	...	...	...	...	...	...	...	+6	+2	+2	−2	...
+1·427											+6		+2	−2
+0·318												+6	−2	
+0·661													+6	−2
−0·009														+6

Normal equations—Continued.

	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}
+0·582						−3·12	+6·63	−7·87	
+0·610						+1·62	−1·42	−1·11	+3·39
+0·602						−1·74	−0·63	+3·03	−3·39
−0·581						+2·98	+2·98	+0·89	+0·28

FIGURE ADJUSTMENT—continued.

Normal equations—Continued.

	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}
+0·733	...	...	...	...	...	......	+0·69	+2·02	+3·85
+0·109						−4·67	+2·51		+1·58
−0·306									−1·99
+1·123							+0·08		−2·96
−1·076		−2						+2·02	+0·28
−1·393	...	...	...	...	...	......	......	+2·61	+3·74
+1·427									
+0·318		+2				−1·11		+1·11	−3·39
+0·661									
−0·009	−2		−2						
o=−0·388	+6	...	...	−2	+2	......	......	... ..	......
−0·500		+6	+2	−2	−2				
−0·060			+6		+2				
+0·890				+6	+2				
−0·210					+6				
+2·23	...	...	...	...	...	+184·19	−31·19	−165·25	+28·10
+2·25							+163·71	−59·21	+15·41
−7·94								+372·25	+1·44
+0·06									+83·73

Normal equations—Continued.

	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}
+ 0·582							
+ 0·610		+15·67		−1·35			
+ 0·602		−15·67		+1·35			
− 0·581				+0·28			
+ 0·733	− 1·99	....	....	+0·28	....	......	......
+ 1·09							
− 0·306	+ 0·25		− 2·46				
+ 1·123	−10·43	−22·10	+ 5·59				
− 1·076		−11·11	+ 8·45	+19·84	− 1·23		−1·23
− 1·393	− 8·36	+18·41	+24·45	+ 1·42	....	.....	......
+ 1·427	− 2·46	− 4·74	+ 6·17	+ 8·45	+19·92		+4·53
+ 0·318		+13·85	+12·55	−15·62	+ 1·23		+1·23
+ 0·661	+11·35	− 1·05	−22·88	+ 5·86	+19·92		+4·53
− 0·009		+ 4·74	+ 4·74		− 9·43	+4·59	+0·06
− 0·388	....	+ 9·31	....	....	−10·39	+8·06	−0·19
− 0·500		+11·11		−11·11	+ 1·23	−2·78	+0·98
− 0·060					+ 4·30	−1·05	−1·30
+ 0·890		− 9·31			− 4·37	+6·43	−0·02

FIGURE ADJUSTMENT—completed.

Normal equations—Completed.

	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}
− 0·210					+ 0·03	+1·76	−1·02
+ 2·23	....	+129·90	....	−11·19	....	......	......
+ 2·25	− 12·75						
− 7·94	− 35·28	−115·49	+ 14·56	+15·65			
+ 0·06	− 87·03	+ 53·12	+ 12·90	− 4·35			
0= − 2·31	+341·85	+250·83	−130·59	+ 9·78			
−26·44	....	+1 955·77	+128·51	−327·70	−98·21	−163·43	− 27·72
+ 1·92			+323·71	− 13·83	−91·23		− 20·75
+ 5·33				+304·55	−49·61		− 49·61
+ 5·65					+1 093·96	+134·41	+202·72
+ 6·26						+ 745·49	+173·99
+ 4·17	....	....	....	....	....	....	+123·66

Resulting values of correlates.

C_1=+0·065 4	C_{11}=−1·407 4	C_{21}=+0·004 65
C_2=−0·215 9	C_{12}=−0·294 9	C_{22}=+0·035 55
C_3=−0·116 3	C_{13}=−0·197 5	C_{23}=−0·102 00
C_4=−0·124 5	C_{14}=−1·422 0	C_{24}=−0·065 29
C_5=−0·824 9	C_{15}=−1·232 6	C_{25}=+0·034 88
C_6=+0·225 0	C_{16}=+1·401 1	C_{26}=−0·074 01
C_7=−0·766 6	C_{17}=−1·460 1	C_{27}=+0·003 11
C_8=+0·036 1	C_{18}=−0·599 2	C_{28}=+0·001 005
C_9=+1·334 3	C_{19}=+1·586 7	C_{29}=+0·030 82
C_{10}=+0·440 0	C_{20}=+0·019 56	C_{30}=−0·021 76

Corrections to angular directions.

″	″	″	″
(1)=−0·067 1	(15)=+0·790 2	(29)=+0·176 6	(43)=−0·030 1
(2)=+0·124 5	(16)=+0·382 2	(30)=+0·012 9	(44)=−0·277 4
(3)=−0·023 7	(17)=−0·786 8	(31)=−0·192 4	(45)=−0·205 9
(4)=−0·033 7	(18)=+0·292 0	(32)=+0·097 0	(46)=−0·048 1
(5)=+0·150 5	(19)=−0·728 6	(33)=+0·082 5	(47)=+0·233 6
(6)=+0·065 4	(20)=+0·268 6	(34)=−0·146 7	(48)=−0·342 6
(7)=−0·440 9	(21)=−0·273 0	(35)=−0·050 6	(49)=+0·382 8
(8)=+0·225 0	(22)=+0·434 3	(36)=−0·133 0	(50)=+0·257 6
(9)=+0·842 8	(23)=−0·688 0	(37)=+0·330 3	(51)=−0·379 6
(10)=−0·007 8	(24)=+0·209 8	(38)=+0·198 2	(52)=+0·183 4
(11)=−0·066 5	(25)=−0·143 0	(39)=−0·144 9	(53)=−0·256 2
(12)=−0·200 9	(26)=−0·344 0	(40)=+0·037 7	(54)=−0·495 4
(13)=−0·567 6	(27)=+0·189 4	(41)=−0·082 2	(55)=+0·614 9
(14)=−0·378 3	(28)=+0·599 2	(42)=+0·021 3	(56)=+0·332 9

Check sum of + corrections = 0·409 6 and Σpvv=6·696

Check sum of − corrections = 0·408 4 $-\Sigma wC$=6·689

Mean error of an observed *direction* $m_1=\sqrt{\frac{[pvv]}{n}}=\pm0''\cdot473$ where n=number of conditional equations; and mean error of an *angle* $m_{\angle}=m_1\sqrt{2}=\pm0''\cdot668$; also probable error of the same $=\pm0''\cdot45$.

TRIANGLES OF THE SALT LAKE BASE NET, UTAH, 1887 TO 1897.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
1	Ogden Peak	30	10	56 ·378	−0 ·114	56 ·264	0 ·196	4 ·049 166 72	11 198 ·677
	S. L. Southeast Base	76	45	51 ·855	−0 ·506	51 ·349	0 ·197	4 ·336 120 31	21 683 ·05
	S. L. Northwest Base	73	03	12 ·986	−0 ·010	12 ·976	0 ·196	4 ·328 533 08	21 307 ·53
				01 ·219			0 ·589		
2	Antelope	34	55	37 ·419	−0 ·464	36 ·955	0 ·169	4 ·049 166 72	11 198 ·677
	S. L. Northwest Base	72	25	10 ·628	−0 ·033	10 ·595	0 ·169	4 ·270 594 77	18 646 ·39
	S. L. Southeast Base	72	39	13 ·041	−0 ·085	12 ·956	0 ·168	4 ·271 152 75	18 670 ·36
				01 ·088			0 ·506		
3	Antelope	16	20	03 ·698	+0 ·071	03 ·769	0 ·171	4 ·328 533 08	21 307 ·53
	Ogden Peak	14	14	52 ·529	−0 ·090	52 ·439	0 ·171	4 ·270 594 76	18 646 ·39
	S. L. Southeast Base	149	25	04 ·896	−0 ·591	04 ·305	0 ·171	4 ·585 977 92	38 545 ·88
				01 ·123			0 ·513		
4	Antelope	18	35	33 ·721	−0 ·535	33 ·186	0 ·194	4 ·336 120 31	21 683 ·05
	S. L. Northwest Base	145	28	23 ·614	−0 ·044	23 ·570	0 ·194	4 ·585 977 93	38 545 ·88
	Ogden Peak	15	56	03 ·849	−0 ·023	03 ·826	0 ·194	4 ·271 152 74	18 670 ·36
				01 ·184			0 ·582		
5	Promontory	25	21	12 ·218	+0 ·563	12 ·781	0 ·558	4 ·336 120 31	21 683 ·05
	Ogden Peak	40	58	29 ·463	+0 ·166	29 ·629	0 ·558	4 ·521 196 00	33 204 ·43
	S. L. Northwest Base	113	40	19 ·411	−0 ·148	19 ·263	0 ·557	4 ·666 302 45	46 376 ·98
				01 ·092			1 ·673		
6	Promontory	26	32	08 ·044	−0 ·680	07 ·364	0 ·515	4 ·271 152 75	18 670 ·36
	S. L. Northwest Base	100	51	16 ·975	+0 ·191	17 ·166	0 ·515	4 ·613 249 36	41 043 ·97
	Antelope	52	36	37 ·141	−0 ·126	37 ·015	0 ·515	4 ·521 196 02	33 204 ·43
				02 ·160			1 ·545		
7	Promontory	51	53	20 ·262	−0 ·117	20 ·145	1 ·267	4 ·585 977 92	38 545 ·88
	Ogden Peak	56	54	33 ·312	+0 ·142	33 ·454	1 ·267	4 ·613 249 34	41 043 ·97
	Antelope	71	12	10 ·862	−0 ·661	10 ·201	1 ·266	4 ·666 302 46	46 376 ·98
				04 ·436			3 ·800		
8	Waddoup	40	14	34 ·375	−0 ·193	34 ·182	0 ·284	4 ·270 594 77	18 646 ·39
	Antelope	39	22	43 ·457	+0 ·158	43 ·615	0 ·284	4 ·262 736 60	18 312 ·03
	S. L. Southeast Base	100	22	43 ·130	−0 ·075	43 ·055	0 ·284	4 ·453 179 57	28 390 ·93
				00 ·962			0 ·852		
9	Waddoup	31	44	35 ·746	−0 ·059	35 ·687	0 ·788	4 ·613 249 35	41 043 ·97
	Antelope	126	54	58 ·017	−0 ·432	57 ·585	0 ·788	4 ·795 001 38	62 373 ·68
	Promontory	21	20	29 ·332	−0 ·240	29 ·092	0 ·788	4 ·453 179 57	28 390 ·93
				03 ·095			2 ·364		

TRIANGLES OF THE SALT LAKE BASE NET, UTAH, 1887 TO 1897—continued.

No.	Stations.	Observed angles. °	′	″	Correction. ″	Spherical angles. ″	Spherical excess. ″	Log s.	Distances in metres.
10	Waddoup	78	09	37 ·309	−0 ·560	36 ·749	0 ·764	4 ·585 977 92	38 545 ·88
	Antelope	55	42	47 ·155	+0 ·229	47 ·384	0 ·765	4 ·512 416 19	32 539 ·90
	Ogden Peak	46	07	38 ·659	−0 ·498	38 ·161	0 ·765	4 ·453 179 56	28 390 ·93
				03 ·123			2 ·294		
11	Waddoup	46	25	01 ·563	−0 ·501	01 ·062	1 ·244	4 ·666 302 46	46 376 ·98
	Promontory	30	32	50 ·930	+0 ·124	51 ·054	1 ·244	4 ·512 416 20	32 539 ·90
	Ogden Peak	103	02	11 971	−0 ·356	11 ·615	1 ·243	4 ·795 001 39	62 373 ·68
				04 ·464			3 ·731		
12	Waddoup	37	55	02 ·934	−0 ·367	02 ·567	0 ·310	4 ·328 533 08	21 307 ·53
	S. L. Southeast Base	110	12	11 ·974	+0 ·666	12 ·640	0 ·309	4 ·512 416 19	32 539 ·90
	Ogden Peak	31	52	46 ·130	−0 ·408	45 ·722	0 ·310	4 ·262 736 60	18 312 ·03
				01 ·038			0 ·929		
13	Deseret	21	11	55 ·626	+0 ·899	56 ·525	1 ·903	4 ·613 249 35	41 043 ·97
	Promontory	35	21	55 ·850	+1 ·111	56 ·961	1 ·903	4 ·817 539 61	65 696 ·10
	Antelope	123	26	12 ·074	+0 ·150	12 ·224	1 ·904	4 ·976 446 90	94 721 ·14
				03 ·550			5 ·710		
14	Deseret	26	36	09 ·648	+0 ·544	10 ·192	3 ·711	4 ·666 302 46	46 376 ·98
	Promontory	87	15	16 ·112	+0 ·992	17 ·104	3 ·712	5 ·014 731 73	103 450 ·29
	Ogden Peak	66	08	42 ·618	+1 ·220	43 ·838	3 ·711	4 ·976 446 89	94 721 ·13
				08 ·378			11 ·134		
15	Deseret	40	45	45 ·533	+0 ·344	45 ·877	4 ·177	4 ·795 001 39	62 373 ·68
	Promontory	56	42	25 ·182	+0 ·871	26 ·053	4 ·177	4 ·902 282 59	79 851 ·41
	Waddoup	82	32	01 ·511	−0 ·909	00 ·602	4 ·178	4 ·976 446 91	94 721 ·14
				12 ·226			12 ·532		
16	Deseret	5	24	14 ·022	−0 ·354	13 ·668	0 ·541	4 ·585 977 92	38 545 ·88
	Antelope	165	21	37 ·064	+0 ·509	37 ·573	0 ·542	5 ·014 731 70	103 450 ·29
	Ogden Peak	9	14	09 ·306	+1 ·077	10 ·383	0 ·541	4 ·817 539 58	65 696 ·10
				00 ·392			1 ·624		
17	Deseret	19	33	49 ·907	−0 ·554	49 ·353	1 ·486	4 ·453 179 57	28 390 ·93
	Antelope	109	38	49 ·909	+0 ·282	50 ·191	1 ·486	4 ·902 282 57	79 851 ·41
	Waddoup	50	47	25 ·765	−0 ·851	24 ·914	1 ·486	4 ·817 539 61	65 696 ·10
				05 ·581			4 ·458		
18	Deseret	14	09	35 ·885	−0 ·200	35 ·685	1 ·709	4 ·512 416 19	32 539 ·90
	Ogden Peak	36	53	29 ·353	−1 ·575	27 ·778	1 ·709	4 ·902 282 57	79 851 ·41
	Waddoup	128	57	03 ·074	−1 ·409	01 ·665	1 ·710	5 ·014 731 73	103 450 ·29
				08 ·312			5 ·128		

TRIANGLES OF THE SALT LAKE BASE NET, UTAH, 1887 TO 1897—continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
19	Pilot Peak	6	08	19·196	−0·344	18·852	2·390	4·666 302 46	46 376·98
	Promontory	154	41	11·298	+0·712	12·010	2·389	5·268 251 87	185 460·69
	Ogden Peak	19	10	35·599	+0·708	36·307	2·390	5·153 734 84	142 473·75
				06·093			7·169		
20	Pilot Peak	14	47	38·925	−0·161	38·764	4·823	4·613 249·35	41 043·97
	Promontory	102	47	51·036	+0·828	51·864	4·824	5·195 235 71	156 760·16
	Antelope	62	24	43·116	+0·726	43·842	4·823	5·153 734 81	142 473·74
				13·077			14·470		
21	Pilot Peak	39	29	58·950	−0·280	58·670	10·541	4·976 446 90	94 721·14
	Promontory	67	25	55·186	−0·282	54·904	10·541	5·138 358 70	137 517·74
	Deseret	73	04	38·915	−0·865	38·050	10·542	5·153 734 82	142 473·74
				33·051			31·624		
22	Pilot Peak	8	39	19·729	+0·183	19·912	3·701	4·585 977 92	38 545·88
	Ogden Peak	37	43	57·713	−0·566	57·147	3·701	5·195 235 69	156 760·16
	Antelope	133	36	53·978	+0·065	54·043	3·700	5·268 251 83	185 460·67
				11·420			11·102		
23	Pilot Peak	33	21	39·754	+0·062	39·816	11·863	5·014 731 72	103 450·29
	Ogden Peak	46	58	07·019	+0·512	07·531	11·863	5·138 358 67	137 517·73
	Deseret	99	40	48·563	−0·321	48·242	11·863	5·268 251 83	185 460·67
				35·336			35·589		
24	Pilot Peak	24	42	20·025	−0·119	19·906	7·621	4·817 539 60	65 696·10
	Antelope	61	01	28·958	−0·576	28·382	7·621	5·138 358 69	137 517·74
	Deseret	94	16	34·541	+0·034	34·575	7·621	5·195 235 70	156 760·16
				23·524			22·863		
25	Mount Nebo	9	37	16·699	−0·082	16·617	3·455	5·138 358 69	137 517·74
	Pilot Peak	7	10	32·730	+0·104	32·834	3·455	5·011 887 45	102 774·99
	Deseret	163	12	20·927	−0·013	20·914	3·455	5·376 158 10	237 770·57
				10·356			10·365		
26	Mount Nebo	51	13	60·600	+0·380	60·980	24·243	5·268 251 84	185 460·68
	Pilot Peak	40	32	12·484	+0·166	12·650	24·243	5·189 173 84	154 587·31
	Ogden Peak	88	14	58·996	+0·104	59·100	24·244	5·376 158 09	237 770·56
				72·080			72·730		
27	Mount Nebo	41	36	43·901	+0·463	44·364	8·925	5·014 731 72	103 450·29
	Deseret	97	06	50·510	+0·333	50·843	8·926	5·189 173 85	154 587·31
	Ogden Peak	41	16	51·977	−0·408	51·569	8·925	5·011 887 45	107 274·99
				26·388			26·776		

TRIANGLES OF THE SALT LAKE BASE NET, UTAH, 1887 TO 1897—completed.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log s.	Distances in metres.
		°	′	″	″	″	″		
28	Ibepah	53	38	37·117	−0·070	37·047	20·887	5·268 251 84	185 460·68
	Pilot Peak	91	02	57·152	+0·115	57·267	20·886	5·362 230 02	230 266·11
	Ogden Peak	35	19	27·891	+0·455	28·346	20·887	5·124 323 42	133 144·56
				62·160			62·660		
29	Ibepah	62	50	30·996	−0·273	30·723	13·091	5·138 358 69	137 517·74
	Pilot Peak	57	41	17·398	+0·053	17·451	13·091	5·116 021 94	130 623·69
	Deseret	59	28	51·521	−0·422	51·099	13·091	5·124 323 41	133 144·55
				39·915			39·273		
30	Ibepah	95	37	53·896	+0·015	53·911	20·671	5·376 158 10	237 770·57
	Pilot Peak	50	30	44·668	−0·051	44·617	20·670	5·265 702 68	184 375·27
	Mount Nebo	33	52	23·387	+0·096	23·483	20·670	5·124 323 43	133 144·56
				61·951			62·011		
31	Ibepah	9	11	53·879	−0·206	53·673	4·067	5·014 731 72	103 450·29
	Ogden Peak	11	38	39·128	+0·058	39·186	4·067	5·116 021 96	130 623·69
	Deseret	159	09	40·084	−0·742	39·342	4·067	5·362 230 02	230 266·11
				13·091			12·201		
32	Ibepah	41	59	16·779	+0·084	16·863	24·027	5·189 173 85	154 587·31
	Ogden Peak	52	55	31·105	−0·351	30·754	24·027	5·265 702 67	184 375·27
	Mount Nebo	85	06	23·987	+0·477	24·464	24·027	5·362 230 01	230 266·10
				71·871			72·081		
33	Ibepah	32	47	22·900	+0·288	23·188	11·034	5·011 887 45	102 774·99
	Deseret	103	43	29·406	+0·409	29·815	11·034	5·265 702 68	184 375·27
	Mount Nebo	43	29	40·086	+0·013	40·099	11·034	5·116 021 95	130 623·69
				32·392			33·102		

PROBABLE ERROR.

Determination of the probable error of the length of the side Ibepah to Mount Nebo of the Main Series of the Triangulation across the Rocky Mountains.

This side is connected with the Salt Lake Base by the following relation:

$$\frac{\text{Ibepah to Mount Nebo}}{\text{Salt Lake Base}} = \frac{\sin(7-6)\sin(3-2)\sin(55-51)\sin(17-14)\sin(28-27)}{\sin(20-16)\sin(52-51)\sin(25-23)\sin(37-36)\sin(32-31)}$$

Hence we have—

$$\begin{aligned} F = {} & \log\sin(7-6) + \log\sin(3-2) + \log\sin(55-51) + \log\sin(17-14) \\ & + \log\sin(28-27) - \log\sin(20-16) - \log\sin(52-51) - \log\sin(25-23) \\ & - \log\sin(37-36) - \log\sin(32-31) \end{aligned}$$

Establishing and solving the transfer equations, we find the reciprocal of the weight or $\frac{1}{p} = 23 \cdot 70$; also the mean error m_p and the probable error r_p both expressed in units of the sixth place of decimals in their logarithms, viz: $\pm 2 \cdot 30$ and $\pm 1 \cdot 55$, respectively; hence—

Log. distance Ibepah to Mount Nebo is $5 \cdot 265\ 702\ 68 \pm 1\ 55$ and the length in metres of this side $= 184\ 375 \cdot 27 \pm 66$.* The probable error equals about $\frac{1}{280\ 000}$ of the length.

To this must be added the uncertainty arising from the base measure viz: $\frac{184\ 375}{11\ 199} \times 7mm = \pm 115mm$; hence we have—

Probable error of length of side Ibepah to Mount Nebo $\sqrt{(0 \cdot 66)^2 + (0 \cdot 115)^2} = \pm 0 \cdot 67$ metre, corresponding to $\pm 3 \cdot 6$ millimetres per kilometre.

GENERAL DESCRIPTION OF TRIGONOMETRIC STATIONS FORMING THE SALT LAKE BASE NET, UTAH.

Salt Lake Southeast Base, Davis County; established by W. Eimbeck in 1896. This station is situated near the eastern shore of Great Salt Lake, about 12 miles in a southwesterly direction from Ogden and about 4½ miles west of Kaysville, a town on the Utah branch of the Union Pacific Railroad. It is in school section 16, township 3 north, range 2 west of the Salt Lake principal meridian, in a large inclosure used as a pasture. The geodetic point is marked by the intersection of two fine cross lines on the head of a copper bolt firmly set in the top of a hard red sandstone block, 2 feet square by 10 inches thick, buried 4 feet and 4 inches below the surface of the ground. This was covered with a layer of earth 6 inches thick, and on this foundation a brick pier was built, rising to a height of 8·8 feet above the ground, surmounted by a capstone, 30 inches square and 5 inches thick. This pier is 4½ feet square at the base, 4 feet square at the surface of the ground, and 26 inches square at the top. At the surface a stone 2 feet square and 10 inches thick was embedded in the middle of the pier, its top surface being flush with the ground and bearing the inscription "U.S.C.&G.S., 1896." A copper bolt, with fine cross lines was firmly set in the stone. The pier is solid from the foundation to the surface, and above that it has a hollow space 12 inches square in the center, with openings at the surface, eastward and in the direction of the base line, to afford access to the surface copper bolt. No reference marks were placed.

Salt Lake Northwest Base, Davis County; established by W. Eimbeck in 1896. This station is situated in South Hooper, about 1½ miles north of Syracuse Grove, on the pasture land of Mr. Cato Love, who lives about 1 148 feet east of the station. It is in the southeast angle of the cross roads at this locality and is 167·3 feet from the fence to the north and 206·2 feet from the fence to the west. Mr. Gil. Parker lives in the nearest house just across the road southwest of the station and Mr. John W. Singleton's house is in the northwest angle of the cross roads.

The geodetic point is marked in precisely the same manner as at Southeast Base, except that the bottom of the brick pier and the top of the subsurface stone are 1 foot and 10 inches nearer the surface of the ground than at Southeast Base.

Ogden Peak, Weber County; established by W. Eimbeck in 1884. This station is situated on a peak of the Wasatch range of mountains, about 10 000 feet above the level

*Equal to 114·564 statute miles ± 2·17 feet, corresponding to ± 0·23 of an inch per mile.

of the sea and about 4 miles in an air line east of the town of Ogden. The west slope of the mountain is very steep and rough; so the station is more easily reached by passing through Ogden Canyon and the town of Huntsville in Cache Valley and approaching it on the east slope of the mountain. The geodetic point is marked by a copper bolt in a hole drilled in the rock. This was covered with a flat stone, having a drill hole in the top surface, cemented in the space between the foot piers of the theodolite stand, and the space between the piers was walled up. The top of the copper bolt is 0·46 feet below the top of the surface mark. As reference marks, 3 holes were drilled in the rock and filled with lead—one bearing north 2° 05′ west, distant 9 feet 7½ inches; one bearing south 71° 17′ east, distant 8 feet 4½ inches, and one bearing south 22° 35′ west and distant 9 feet 4 inches from the geodetic point. Bearings are true. A ring wall of stones, nearly 15 feet in diameter, built to serve as a wind-break, was left standing.

Antelope, Davis County; established by W. Eimbeck in 1887. This station is situated on the largest island in Great Salt Lake, known as Church or Antelope Island. The island is in the southeastern part of the lake, and is about 15 miles long north and south and 5 miles wide in the widest part. The station is about 2 400 feet above the level of the lake, near the middle of the island, and on the highest peak of the low mountain range extending nearly its whole length. The geodetic point is marked by a copper bolt set in the solid rock at the south end of the small, nearly flat, top of the peak. A hollow brick pier, about 6 inches thick and 28 inches square, was built around this bolt and covered with a red sandstone cap block 2½ inches thick and 28 inches square. The inscription "U.S.C.& G.Survey, 1892" was cut on its top surface and in its center is a copper bolt inclosed in a triangle. The distance between the tops of the two copper bolts is 8½ inches. Around the pier and concentric to the station bolt was built a rock wall, 4 feet high and 2 feet thick, with an outer diameter of 14 feet, to serve as a wind-break. Just outside of this ring wall 3 drill holes were made in the solid rock, as reference marks—one bearing a little west of north, distant 8 feet 5$\frac{5}{16}$ inches; one about east southeast, distant 7 feet 6⅝ inches, and one about southwest, distant 7 feet 11½ inches from the geodetic point.

Promontory, Boxelder County; established by W. Eimbeck in 1887. This station is situated on the southern summit of the eastern ridge of a low, broken range of mountains—the highest summits being about 2 500 feet above the level of the lake—on the Promontory peninsula extending into Great Salt Lake from the north. On the ridge a short distance northwest of the station there are several summits higher than the one on which the station is located. The geodetic point is marked by a cross on a copper bolt set in the solid rock, around which was built a hollow brick pier 32 inches square, 8 inches thick, and 12 inches high, covered with a red sandstone cap block 2½ inches thick, having the inscription "U.S.C.& G.Survey, 1892" cut on its top surface and in its center a copper bolt inclosed in a triangle. The distance between the tops of the two copper bolts is 15½ inches. The usual rock wall, for a wind-break, was built about 3 feet high and with an outer diameter of 16 feet. Just outside the rock wall 3 drill holes were made as reference marks—one bearing about northeast by north, distant 8·2 feet; one about southeast, distant 8 feet, and one about west by south, and distant 8·9 feet from the geodetic station.

Waddoup, Davis County; established by W. Eimbeck in 1892. This station is situated 88 feet north and 288 feet west of the southeast corner of the northwest

quarter of section 18, township 2 north, range 1 east of the Salt Lake principal meridian, in the west side of Thomas Waddoup's barnyard, 80 feet west of his house. It is one-half mile west of the Davis County public road, the principal thoroughfare between Ogden and Salt Lake City. Centerville station, on the Union Pacific Railroad, is located at the northwest corner of section 18. The geodetic point is marked by a copper bolt set in the top of a granite post, 2 feet long with head dressed to 7 inches square, buried 2 feet below the surface of the ground. A hollow brick pier, 32 inches square outside and 16 inches inside, covered with a red sandstone cap block 4 inches thick, having the inscription "U.S.C.& G.Survey, 1892" cut on its top surface, and a drill hole in the center inclosed in a triangle, was built up from the top of the granite post to about 4 feet above the surface of the ground.

Deseret, Tooele County; established by W. Eimbeck in 1887. This station is situated on the *summit* of the *highest peak* of the Onagui Mountains, about 11 200 feet above sea level. It is about 8 miles, in an air line, a little west of south of the town of Grantsville and about 12 miles, in an air line, west of the town of Stockton, and between 8 and 9 miles in a southwesterly direction, by trail, from Fenstermaker's ranch in the entrance to Boxelder Canyon. The geodetic point is marked by a copper bolt set in the rock, encircled by a rock wall, as a wind-break, about 4 feet high and 14 feet 3 inches outer diameter, concentric with the copper bolt. Just outside the rock wall 3 drill holes were made in the rock, as reference marks—one bearing south 43° 53′ east, distant 10 feet 2 inches; one bearing south 81° 22′ west, distant 7 feet 2 inches, and one bearing north 18° 38′ east, distant 8 feet 7 inches from the geodetic point. Bearings are true.

Pilot Peak, Elko County, Nevada; established by W. Eimbeck in 1887. This station is situated on an almost inaccessible and very rugged peak, the most southern and highest of a prominent range of mountains near the northwestern border of the Great American Desert. It is about 25 miles south of Tecoma, Nevada, a station on the Central Pacific Railroad, and is about 10 764 feet above sea level. Knaul's ranch, 10 miles to the north, is the only one in the vicinity. The geodetic point is marked by a copper bolt set in the rock, encircled by a rock wall 4½ feet high and 16 feet outer diameter, concentric with the copper bolt. Four drill holes were made in the rock, as reference marks—one bearing south 35° 01′ east, distant 9 feet 9 inches; one bearing south 47° 35′ west, distant 9 feet 9½ inches; one bearing north 56° 31′ west, distant 8 feet 11½ inches, and one bearing north 9° 13′ east and 8 feet 9 inches distant from the geodetic point. The latitude station brick pier bears east 6° 26′ south and is distant 41 feet 6 inches from the central bolt.

Mount Nebo, Juab County; established by W. Eimbeck in 1883. This station is situated on the southernmost summit of the Mount Nebo range of mountains, at an elevation of about 11 940 feet above sea level. It is about 16 miles in a northeasterly direction, by wagon road and trail, from Nephi, the county seat of Juab County, a station on the Utah Southern Railroad, about 93 miles south of Salt Lake City. The geodetic point is marked by a copper bolt, with cross on it, firmly set in the solid rock, with the usual brick pier for the theodolite and rock wall wind-break built around it. The brick latitude pier, with wind-break wall around it, bearing south 38° 25′ east, distant 76·28 feet from the geodetic point, was left standing. Four holes were drilled in the solid rock, as reference marks—one bearing north 24° 16′ east, distant 13·94 feet;

one bearing south 50° 21′ east, distant 10·89 feet; one bearing south 38° 01′ west, distant 8·4 feet, and one bearing north 58° 32′ west, and distant 8·73 feet from the geodetic point. All bearings are true.

Ibepah, Juab County; established by W. Eimbeck in 1881. This station is situated on the highest point of the southernmost peak of the Deep Creek range of mountains, on the southwest border of the Great Salt Lake Desert, at an elevation of about 12 106 feet above sea level. This peak, as seen from the valley below, resembles a house top, with roof and gables well defined. It is about 15 miles south by east from Ibepah post-office and about 2 miles northeasterly from two very prominent twin peaks of a bold red color. The geodetic point is marked by a copper bolt, with cross on it, sunk in the solid rock, encircled by the usual rock wall, 16 feet outer diameter and 4 feet high. The brick latitude pier, with wind-break wall around it, bearing north 71° 09′ west, distant 69 feet 8 inches from the geodetic point, was left standing. Four holes were drilled in the solid rock, as reference marks—one bearing north 66° 20′ east, distant 9 feet 8¾ inches; one bearing south 59° 48′ east, distant 10 feet 1 inch; one bearing north 88° 28′ west, distant 10 feet 8 inches, and one bearing north 45° 28′ west, distant 10 feet 5 inches from the geodetic point. All bearings true.

(*j*) *Versailles Base Line*, *Missouri*, *1897*.

LOCATION, MEASUREMENT AND LENGTH.

Location of the base line.—The Versailles base is located on the divide between the Missouri and Osage rivers, near the town of Versailles, Morgan County, Missouri. The site for this base was originally selected, as early as 1878, under the direction of Assistant J. A. Sullivan, and its two terminals known as North Base and Hunter were occupied for angular measures in 1880 by Assistant F. D. Granger. The approximate length of the base is 7·64 kilometres, its middle point is in latitude 38° 27′·7 and in longitude 92° 47′·4, and its azimuth at Hunter is about 157° 50′. The elevation above the sea level is about 311 metres.

The measurement of the base.—The measurement of the line was placed under the charge of A. L. Baldwin, Assistant, and was accomplished by his party during May and June, 1897.

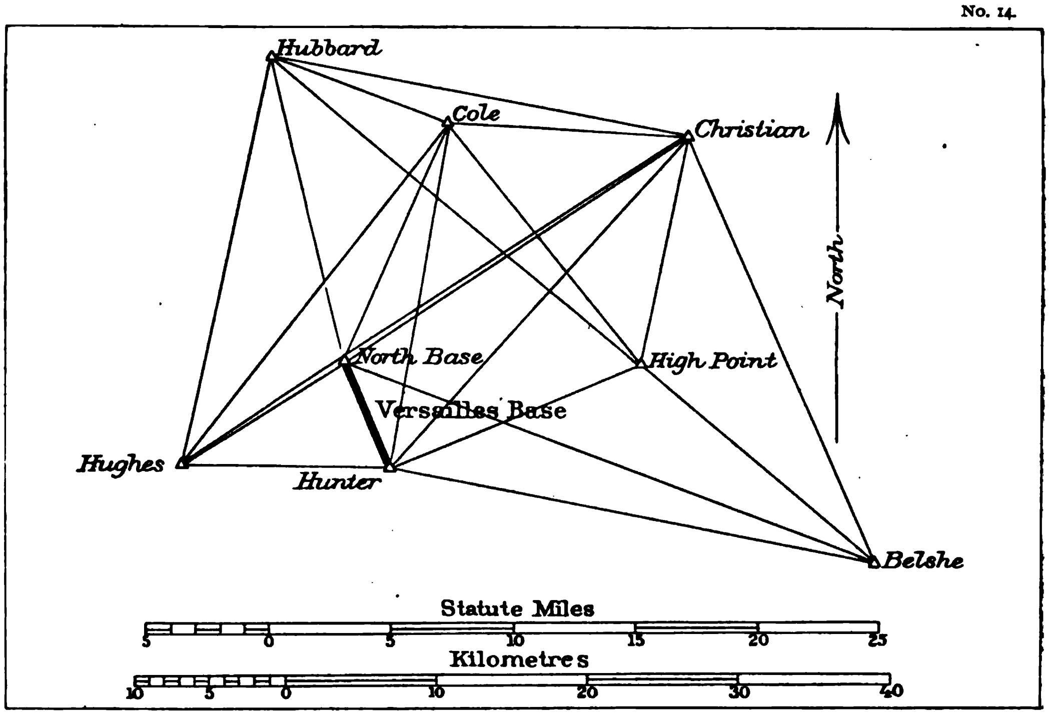
The levels for the profile and the determination of the absolute height of the line depend on the height of bench mark No. XXXV of the transcontinental line of levels, at Tipton, Missouri, as established in 1891. During June, 1897, lines of spirit levels were run between North Base and Hunter and between North Base and the Tipton bench, mostly by H. F. Flynn—the latter distance is about 20 statute miles.

The line crosses cultivated land for almost its entire length. Section stones with copper bolt and cross lines were set at 1, 2, and 7 kilometres from North Base. Each stone is set in cement and projects from 4 to 12 inches above the surface. Other kilometres were marked by posts with copper tack. At North Base the center stone and bottle of ashes, as secured in the ground in 1878, were replaced by rough-dressed sandstones each with copper bolt and cross lines. The two blocks are set in concrete and cement one above the other, the space of 23 centimetres between them being filled by four pieces of pine. At Hunter also the station was similarly re-marked in 1897. These surface stones are inscribed U.S.C.&G.S. 1897. The line was further prepared for measure by the removal

of fences, hedges, and other obstacles; and stakes were aligned for use with the 50-metre steel tape to serve as marking stakes for the ends and support stakes for the middle of the tape. In setting these support stakes, of which there was one for each tape length, care was taken to make the spaces between the supporting nail and the marking tables uniform and to bring them into coincidence with the line of slope as near as could be without the use of a level. This work occupied the time between May 29 and June 5.

(1) *Measures by metallic tape.*—Between June 8 and 15 two complete measures (one north and one south) were made over the whole line and two more over the third, fourth, and fifth kilometres. The complete measures were made at night, either with falling or stationary temperature, the remaining ones before and after daybreak with stationary

No. 14.



or rising temperature. The 50-metre steel tape No. 204 was used under a tension of 15 kilogrammes. Two thermometers were tied to the tape about a metre from the marking sleeves and read immediately after contact was made. Just before contact was made and with the tape under given tension it was slightly raised at the middle and forward end to relieve friction. For a full account of the method and apparatus of tape measures, see Coast and Geodetic Survey Report for 1892, pp. 329–503; also Coast and Geodetic Survey Report for 1894, part 2, Appendix No. 5, on the length of the Holton Base, Indiana.

(2) *Measures with the 5-metre steel rods Nos. 13 and 14.**—With a view of controlling the tape measure of the base, its fourth kilometre was measured three times with the above contact-slide bars, between June 16 and 24. Two of the measures were

*For general description of contact-slide bars and accessories, see Coast and Geodetic Survey Report, 1880, Appendix 17, pp. 341–344.

southward and one northward. The bars were aligned by means of a 20-centimetre transit. Pointing was made on the agate ends. The line passes over meadows intersected by wide furrows; this, with severe rains encountered on nearly every day and the necessity of measuring through a barnyard and two stables, where the portable trestles could not be used, made speed impossible.

The standardization of the steel rods Nos. 13 and 14.—The length of these rods has been determined on two occasions—viz, in connection with the measure of the Holton Base, Indiana, in 1891,* and again in connection with the Salina Base, Kansas, 1896. The results were:

	At Washington in vault, July, 1891.	At the Holton Camp, August, 1891.	At the Holton Base, September, 1891.	At the Holton Base kilometre, 1891.
Length of No. 13 at 22°·2 C.	$5m + 1\ 278\mu \pm 4\mu$			
Length of No. 14 at 22°·2 C.	$5m + 1\ 297\mu \pm 3\mu$			
Σ (13 + 14)†	$10m + 2\ 575\mu \pm 5\mu$ + 30	$10m + 2\ 608\mu \pm 5\mu$	$10m + 2\ 609\mu \pm 6\mu$	$10m + 2\ 618\mu \pm$?

The following result was obtained at the 50-metre test line south of the office building at Washington, between February and April, 1896, viz: $10m + 2\ 609\mu \pm 7\mu$ at 22°·2 C. The coefficient of expansion was determined by Assistant O. H. Tittmann and Mr. L. A. Fischer between May 18 and 27, 1891, at the office vault. They found the value $0{\cdot}000\ 011\ 776 \atop \pm 27$ for No. 13 and $0{\cdot}000\ 011\ 714 \atop \pm 29$ for No. 14, and for the mean rod the expansion $11{\cdot}745\mu \atop \pm 28$ per metre and centigrade scale. It was desirable to submit the result for length of bars Nos. 13 and 14 to a check after their return from the base, to make sure that no change had occurred. The arrangement and procedure were the same as had been adopted before, viz: The length of the office test line was measured with the bar-in-ice apparatus No. 17 (length = $5m - 16{\cdot}2\mu \pm 1{\cdot}1\mu$) and then redetermined by means of the joined bars Nos. 13 and 14, as well as by the tape No. 204. Length of the 50-metre office test line‡ between its two bronze bolts, as measured with the bar-in-ice No. 17 by A. Braid, L. A. Fischer, and A. L. Baldwin—

	h. m. h. m.	Direction of measure.	Length. mm.	
1897. Oct. 14.	11 26 a. m. — 12 00	Eastward, sunshine.	50m + 0·41	
	0 20 p. m. — 0 44 p. m.	Westward, sunshine.	+ 0·44	
Oct. 15.	2 21 p. m. — 2 50 p. m.	Eastward, sunshine.	+ 0·32	Mean.§
	3 05 p. m. — 3 25 p. m.	Westward, sunshine.	+ 0·37	50m + 0·374mm. ± 0·016.
Oct. 18.	10 25 a. m.	Eastward.	+ 0·32	
	11 16 a. m. — 12 00	Westward.	+ 0·45	
	3 35 p. m.	Eastward, sunshine.	+ 0·30	

*See Appendix No. 5, report for 1894.

†When put together, 30μ should be added for slant of knife edges.

‡The shed was completed in January, 1896; the roof is covered with tin and painted dark.

§The length between the bolts is again nearly as it was in 1896, showing a swaying back of the concrete blocks since the last comparisons.

Measure of the test line in terms of bars 13 and 14, October 18, 1897.—Table of corrections to thermometers Nos. 1, 2, 3, and 4, attached to the bars 13 and 14. These thermometers have metallic backs; the graduation is on the centigrade scale. Nos. 1 and 2 are on bar 13, and 3 and 4 on bar 14.

Temperature.	No. 1.	No. 2.	No. 3.	No. 4.	Mean.
°	°	°	°	°	°
0 ·0	—0 ·27	—0 ·30	—0 ·05	—0 ·30	—0 ·23
3 ·0	·33	·59	·23	·47	·40
6 ·0	·28	·54	·14	·41	·34
11 ·0	·30	·53	·16	·40	·35
16 ·0	·34	·52	·17	·41	·36
21 ·0	·43	·56	·21	·43	·41
25 ·0	·33	·51	·26	·48	·40
32 ·0	·38	·56	·27	·50	·43
34 ·0	·39	·57	·32	·54	·46
37 ·0	—0 ·43	—0 ·63	—0 ·28	—0 ·50	—0 ·46

For convenience, the five measures with the bars were referred to the terminal microscopes A and B instead of to the centers of the bronze bolts. All measures being made on the 18th of October, we deduct the measures involving the cut-off apparatus from the above three measures with the bar-in-ice, and refer the length to the microscopes; hence—

Length of test line between terminal microscopes October 18	49 ·999 50
	49 ·999 62
	49 ·999 44
Mean value adopted	49 ·999 52

This length is to be increased by 7 millimetres for shift of microscopes. The coefficient of expansion of these rods was carefully ascertained in May, 1891, with the results as previously given. The following table gives the particulars of the five measures with the resulting value for the combined length of the two bars or for $\Sigma\,(13 + 14)$ at 0° C.

No.	October 18, 1897. Time of day.		Mean temperature corrected.	Difference W.-E.	Grade correction.	Effect of expansion.	½ length of joined bars, or ½ Σ (13+14) at 0° C.
	h. m.	*h. m.*	°				
1	1 05 p. m. to	1 38	+11 ·565	+ 101μ	—144μ	6 789μ	5*m*—23μ*
2	1 38	2 00	12 ·140	— 468	—159	7 126	+ 2
3	2 00	2 21	12 ·592	— 707	—158	7 391	— 1
4	2 21	2 40	13 ·026	— 996	—163	7 646	+ 3
5	2 40	.. ..	+13 ·405	—1 166	—157	7 869	— 3

*Rejected by observer; trestles disturbed during measure.

Mean of four measures $\Sigma\,(13+14)$ at 0° C. $= 10$ metres $+ 0{\cdot}5\mu \pm 2\mu$, a value which may be regarded as practically identical with that found in February, March, and April, 1896, in connection with the Salina Base.* Taking into account the probable error of the measure with the bars as well as that of the base and standard, we get—

$$\Sigma\,(13+14) \text{ at } 0^\circ \text{ C.} = 10 \text{ metres} + 0{\cdot}5\mu \pm 3{\cdot}5\mu \text{ nearly.}$$

Measure of the test line in terms of the 50-metre steel tape, No. 204.—On May 19 and 20, and again on October 14 and 15, 1897, a number of comparisons for length of tape were made. The tape was stretched over the test line with a tension of 15 kilogrammes and compared with the distance between the terminal microscopes, and when the difference in length became too great for microscopic measure, by reason of expansion or contraction of the tape due to changed temperature, the east microscope was shifted a certain number of millimetres by means of the Brunner centimetre scale. During the measures the tape was supported at three points—viz, directly under the microscopes and at the middle point. Near the same places thermometers with metallic backs were placed flat upon the upper surface of the tape. The illumination needed for reading of the microscopes was by means of a signal lamp placed outside the comparing shed. The mean value for one turn or revolution of the microscope micrometres A and B is $71{\cdot}6\mu$.

The observations made in May, before the base measure, are less elaborate and not quite so satisfactory as those of October; they are, nevertheless, of value, since they prove the constancy of the length of the tape after its use in the field. In the spring observations but two thermometers were read, and the resulting values for length of tape show a progressive increase as the observations were progressing. On May 19 and 20 the distance between the microscopes A and B was determined by means of the bar-in-ice No. 17, and on the same days the length of the tape was tested.† The results were: 49·986 0 metres from fourteen measures with falling temperature ($26\frac{1}{2}^\circ$ to 17°); 49·986 4 metres from seven measures with stationary temperature ($16\frac{1}{2}^\circ$), and 49·986 6 metres from eight measures with rising temperature ($20\frac{3}{4}^\circ$ to $26\frac{1}{2}^\circ$). This last value, as will be seen farther on, is identical with the value deduced from the October observations. The difference between groups 1 and 3 is ascribed, by the principal observer, to lag of thermometers. Respecting the October observations, we have to note the following particulars:

* Viz, 10 metres $+ 1\mu \pm 7\mu$, see account of the Salina Base measure of 1896; the probable error given here and above in the text refers only to discrepancies in the comparisons and are not absolute.

† The observations were in charge of A. Braid, who was aided by A. L. Baldwin, L. A. Fischer, and other help.

Table of thermometer corrections.

Temperature.	No. 7874 at east end.	No. 7871 at middle.	No. 7868 at west end.	Mean adopted.
°	°	°	°	°
0·0 C.	−0·18	−0·07	−0·00	−0·08
2·5		−0·11	−0·11	−0·13
5·0	−0·16	−0·13	−0·08	−0·12
7·5		−0·14	−0·06	−0·12
10·0	−0·18	−0·24	−0·07	−0·16
12·5		−0·23	−0·11	−0·17
15·0	−0·18	−0·21	−0·14	−0·18
17·5		−0·23	−0·13	−0·19
20·0	−0·22	−0·28	−0·09	−0·20
22·5		−0·27	−0·09	−0·18
25·0	−0·14	−0·28	−0·17	−0·20
27·5		−0·24	−0·16	−0·17
30·0	−0·06	−0·26	−0·14	−0·15
32·5		−0·24	−0·24	−0·18
35·0	−0·08	−0·26	−0·19	−0·18
37·5		−0·23	−0·30	−0·20
40·0	−0·06	−0·20	−0·31	−0·19

On October 14 and 15 the distance between the microscopes of the office test line was found as follows:

October 14	49·999 187	
October 14	223	
October 15	095	a correction of + 1 millimetre was applied for shifting of microscopes.
October 15	141	
Mean	49·999 16	

For the reduction of the length of the tape to 0° C., the coefficient of expansion 0·000 011 was employed. The 38 measures were divided into two groups, one of high, the other of low, temperature.

(1) Length of tape at 0° C. from 17 measures, October 14, between 2 hours 30 minutes p. m. and 9 hours 30 minutes p. m., and between 9 hours 25 minutes a. m. and 0 hours 30 minutes p. m. October 15, at a mean temperature 20°·50, 49.986 66 metres.

(2) Length of tape at 0° C. from 21 measures between 0 hours 03 minutes p. m. and 6 hours 48 minutes a. m. October 15, at a mean temperature 14°·23, 49·986 49 metres.

Value for length of tape 204 at 0° C., 49·986 57 metres + 0·55 *t* millimetre, under
± 3
tension and support as stated.

Measures and results for length of the Versailles Base Line.—Between June 8 and 15 two complete measures of the base were had with the tape, also two additional measures of the third, fourth, and fifth kilometres, and between June 16 and 24 three measures

were secured of the fourth kilometre by means of the contact-slide bars.* These last measures were intended to furnish the means for a restandardization of the tape under better conditions as to surroundings than existed when this was done under the covered shed at Washington, where the heat radiation, in particular from the ground, was obstructed, as compared with the free radiation in space. The results for the length of the fourth kilometre space will therefore be given first.

The corrections to the four thermometers, Nos. 1 to 4, are those already tabulated, and they were applied, as well as those for inclination of bars, as below:

	h. m.	h. m.		°
First measure southward, June 16	5 50 a. m. and	10 22 a. m.		25·81
18	6 07	9 09		
19	6 03	10 29	Mean temperature t	
Second measure southward, June 21	5 18	6 33	corrected for gradation errors.	24·34
22	5 09	11 12		
23	5 17	6 02		
Third measure northward, June 23	6 21	10 11		25·47
24	9 38	12 59		

	m μ m	Corr'n for slope.	Excess.	Resulting length.
Length of fourth kilometre space, 100 bars 13 and 14 at t°.	1 000+50+0·303 14	−0·122 10	−0·207 36	999·973 7
	±350 ± 37			
	+0·285 87	−0·116 39	−0·196 23	·973 3
	± 33			
	+0·299 15	−0·128 78	−0·199 55	·970 9
	± 35			
		Mean of 3 measures		999·972 6

The probable error of this mean due to measurement is ±0·59 millimetre, that due to temperature, ±0·35 millimetre, and that due to the joined length of 13 and 14, ±0·35 millimetre; total, ±0·78 millimetre.

*Mr. Baldwin was assisted by Mr. R. L. Faris and H. F. Flynn.

MEASURES OF THE FOURTH KILOMETRE BY MEANS OF THE TAPE.

Thermometers No. 7874 and No. 3666 were placed in contact with the forward and rear ends of the tape, respectively. The graduation corrections for the latter instrument and for the mean of the two instruments are as follows:

Thermometer 3666.				Therm's 3666 and 7874.	
Temp.	Corr'n.	Temp.	Corr'n.	Temp.	Mean Corr'n.
°	°	°	°	°	°
0·00 C	+0·10	22·60 C	+0·09	0 C	−0·04
2·60	·08	24·84	·07	5	·06
4·95	·05	27·41	·06	10	·07
7·59	·07	30·02	·05	15	·055
10·00	·03	32·50	·03	20	·075
12·54	·04	35·05	·00	25	·035
15·07	·07	37·61	·04	30	·00
17·37	·10	40·02	+0·00	35	·04
20·04	+0·07			40	−0·03

Length of fourth kilometre space.

No.	Date.	Hour of day.	Mean temp. corr'd.	Corr'n for expansion.	Corr'n for inclination.	Sum of set-ups.	Sum.
	1897.	h. m. h. m.	°		m.	m.	m.
1	June 8	8 30 p. m. to 9 30 p. m.	+14·17	+0·155 9	−0·108 8	+0·184 6	+0·231 7
2	10	7 40 " 8 22 "	20·63	0·226 9		0·112 8	0·231 0
3	14	4 42 a. m. to 5 10 a. m.	18·83	0·207 1		0·130 8	0·229 2
4	15	4 38 " 5 00 "	19·89	0·218 8		0·122 6	0·232 6
						Mean	0·231 1
							± 5

$$\text{and 20 T. at } 0^\circ\text{ C.} + \underset{\pm 5}{\overset{m}{0{\cdot}231\ 1}} = \underset{\pm 8}{999{\cdot}972\ 6}$$

hence length of tape at 0° C., $\underset{\pm 5}{49{\cdot}987\ 10}$ metres, a value corresponding well with that found at the test line in Washington ($\underset{\pm 3}{49{\cdot}986\ 57}$). We shall make use of the result as found from the field comparisons.

Abstract of measures of the Versailles Base by means of tape No. 204.

No. of kilometre and tapes.	Date, 1897.	Direction.	Mean temp. corr'd.	Correction for temp. of tape.	Correction for inclination.	Set-ups (or set-backs.)	Resulting length of parts.	Diff. from mean.
			°	*m.*	*m.*	*m.*	*m.*	*mm.*
1 0 or North Base to 20	June 10	N.	20·17	+0·221 9	−0·402 4	+0·034 9	999·595 8	−1·9
	June 11	S.	24·95	·274 4		−0·021 5	·592 0	+1·9
							·593 9	
2 20 to 40	June 11	S.	23·70	+0·260 7	−0·212 9	+0·048 4	999·837 7	+0·5
	June 11	N.	22·59	·248 5		+0·061 5	·838 6	−0·4
							·838 2	
3 40 to 60	June 8	S.	15·86	+0·174 5	−0·086 6	+0·129 5	999·958 8	+1·2
	June 10	N.	19·57	·215 3		+0·089 9	·960 0	0·0
	June 14	S.	17·97	·197 7		+0·106 1	·958 6	+1·4
	June 15	S.	19·89	·218 8		+0·089 2	·962 8	−2·8
							·960 0	
4 60 to 80	June 8	S.	14·17	+0·155 9	−0·108 8	+0·184 6	999·973 2	−0·6
	June 10	N.	20·63	·226 9		+0·112 8	·972 5	+0·1
	June 14	S.	18·83	·207 1		+0·130 8	·970 7	+1·9
	June 15	S.	19·89	·218 8		+0·122 6	·974 1	−1·5
							·972 6	
5 80 to 100	June 8	S.	13·94	+0·153 3	−0·131 8	+0·106 0	999·869 0	−2·4
	June 9	N.	17·40	·191 4		+0·066 5	·867 6	−1·0
	June 14	S.	19·85	·218 4		+0·035 9	·863 9	+2·7
	June 15	S.	20·00	·220 0		+0·036 4	·866 1	+0·5
							·866 6	
6 100 to 120	June 8	S.	13·53	+0·148 8	−0·107 8	+0·174 3	999·956 8	−1·6
	June 9	N.	18·01	·198 1		+0·121 7	·953 5	+1·7
							·955 2	
7 120 to 140	June 8, 9	S.	16·90	+0·185 9	−0·443 2	+0·148 5	999·632 7	+0·5
	June 9	N.	18·41	·202 5		+0·132 9	·633 7	−0·5
							·633 2	
8 140 to 153 or Hunter	June 9	S.	19·01	+0·135 9	−0·302 5	+0·138 8	649·804 2	−0·2
	June 9	N.	18·91	·135 2		+0·139 2	·803 9	+0·1
							·804 0	

The fractional part of a tape, between Hunter △ and the end of tape 153, was measured by means of a 3-metre steel bar, one of the metre spaces being graduated to

centimetres and read by a vernier to 0·05 of a millimetre. Corrections to subdivisions are given:

Distance: 2·217 65 metres at 42°·8 C.
2·179 00 metres at 35°·2 C.
End of tape 153 to Hunter = 4.397 9 metres.
Sum of parts of base (1 to 8) 7 648·623 7 metres.

Hence length of base (unreduced to sea level) 7 644·225 8 metres.

To reduce the measured length to the sea level, we have the following data: Provisionally adopted height of the St. Louis, Missouri, City Directrix, so called, or bench mark K_3 (on the great bridge) of the transcontinental line of spirit leveling 125·8 metres ± 0·25 metre.

Δh Tipton, city hotel bench mark XXXV and K_3 by spirit levels, 1882–1888–1891	155·74
Δh bench mark at Fortuna, Gunter's store, and Tipton by spirit levels, 1897	13·66
Δh Versailles North Base, bolt in stone and Fortuna bench mark by spirit levels, 1897	26·63
Height of North Base	321·83

From leveling of the base in May, 1896, and in June, 1897, we get the mean heights of the several kilometres, as follows: *

	m.		m.
No. 1	316·91	No. 5	318·08
2	311·28	6	308·14
3	303·46	7	302·60
4	312·04	8	315·06

Average height above the sea of whole base h = 310·81 metres, and the reduction to sea level becomes $-b.\frac{h}{\rho} = -0{\cdot}373\,3 \pm 6$ metre, where ρ = radius of curvature in the latitude and azimuth of the base.

The probable error of the base measure, as derived from the discord of the several measures of the segments by the tape, is given by the expression—

$$0{\cdot}674\sqrt{\frac{\Sigma(\sigma_1-s_1)^2}{n_1(n_1-1)}+\frac{\Sigma(\sigma_2-s_2)^2}{n_2(n_2-1)}+\frac{\Sigma(\sigma_3-s_3)^2}{n_3(n_3-1)}+\cdots}$$

where for any segment n = number of measures and $\Sigma(\sigma-s)^2$ the sum of the squares of the individual differences from the mean value σ. This probable error equals ± 2·08 millimetres; hence we have finally—

	mm.	
Probable error of measure	± 2·08	total ± 7·95 mm.
Probable error of reduction to sea level	0·60	
Probable error of 153 tapes (153 × ·000 05)	7·65	

which is about $\frac{1}{960\,000}$ of the length.

Length of the Versailles Base	7 643·852 5 ± 8 0
and its logarithm	3·883 312 3 ± 5

* The height above sea of Hunter, copper bolt in stone, = 319·0 metres.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE NET, 1879–80.

Versailles North Base, Morgan County, Missouri. August 16 to August 28, 1880. 35-centimetre theodolite, No. 10. Telescope above ground 9·33 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Correction from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
6	Hunter (Versailles South Base)	0	00	00·00	±0·10	+0·31	00·31
7	Hughes	80	28	22·95	·16	+0·07	23·02
1	Hubbard	188	27	27·11	·14	−0·14	26·97
2	Cole	225	40	19·15	·14	+0·12	19·27
3	Christian	258	39	45·10	·13	+0·07	45·17
4	High Point	292	35	48·80	·14	−0·28	48·52
5	Belshe	312	31	39·77	·16	−0·17	39·60

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·81.

Hunter (*Versailles South Base*), Morgan County, Missouri. July 21 to July 30, 1880. 35-centimetre theodolite, No. 10. Telescope above ground 12·46 metres. F. D. Granger, observer.

		°	′	″	″	″	″
9	Versailles North Base	0	00	00·00	±0·13	−0·24	$\overline{59}$·76
	Tipton spire	21	18	61·21	·42		
10	Cole	32	02	47·08	·20	+ ·25	47·33
	California spire	60	37	21·99	·31		
11	Christian	63	57	44·28	·17	− ·12	44·16
12	High Point	89	29	18·05	·20	− ·80	17·25
13	Belshe	122	37	04·11	·15	+ ·79	04·90
8	Hughes	293	39	12·55	·16	+ ·11	12·66

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·04.

Hughes, Morgan County, Missouri. September 8 to September 26, 1880. 35-centimetre theodolite, No. 10. Telescope above ground 32·19 metres. F. D. Granger, observer.

		°	′	″	″	″	″
17	Versailles North Base	0	00	00·00	±0·10	−0·04	$\overline{59}$·96
18	Hunter (Versailles South Base)	33	10	50·59	·12	− ·20	50·39
	Schnackenberg	229	36	09·83	·17		
	Sedalia, German Methodist Church spire	261	32	53·97	·44		
	Heard	264	26	26·61	·14		
14	Hubbard	314	13	16·91	·13	− ·32	16·59
15	Cole	339	57	16·87	·14	− ·20	16·67
16	Christian	358	46	13·33	·21	+ ·75	14·08

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·90.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE NET, 1879–80—continued.

Cole, Moniteau County, Missouri. October 12 to October 22, 1880. 35-centimetre theodolite, No. 10. Telescope above ground 12·47 metres. C. Terry, jr., observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Correction from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
29	Hubbard	0	00	00·00	±0·11	+0·47	00·47
	Tipton spire	6	35	31·72	·58		
	California spire	160	22	40·59	·30		
24	Christian	162	47	10·72	·21	+ ·02	10·74
	Moreau	184	00	44·49	·18		
25	High Point	211	20	25·86	·22	− ·50	25·36
26	Hunter (Versailles South Base)	259	34	20·25	·20	+ ·32	20·57
27	Versailles North Base	273	11	52·42	·14	− ·22	52·20
28	Hughes	287	57	13·07	·19	− ·08	12·99

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·08.

Hubbard, Morgan County, Missouri. October 29 to November 12, 1880. 35-centimetre theodolite, No. 10. Telescope above ground 13·99 metres. F. D. Granger and T. P. Borden, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
20	Cole	0	00	00·00	±0·10	+0·27	00·27
21	High Point	19	27	23·21	·16	− ·95	22·26
22	Versailles North Base	55	58	59·68	·14	+ ·57	60·25
23	Hughes	82	13	13·27	·16	+ ·31	13·58
	Schnackenberg	125	22	11·35	·18		
	Sedalia spire	166	10	13·78	·22		
	Heard	168	31	22·35	·17		
19	Christian	350	25	26·60	·14	− ·20	26·40

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·90.

Christian, Moniteau County, Missouri. October 25 to November 7, 1879. 35-centimetre theodolite, No. 10. Telescope above ground 12·28 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
37	High Point	0	00	00·00	±0·09	+0·40	00·40
38	Hunter (Versailles South Base)	30	12	30·25	·21	− ·68	29·57
39	Versailles North Base	44	54	30·92	·18	− ·37	30·55
40	Hughes	45	29	22·83	·22	− ·29	22·54
41	Cole	81	30	23·13	·18	+ ·70	23·83
	Tipton, Baptist Church spire	87	02	15·50	·22		
42	Hubbard	89	08	40·05	·16	− ·21	39·84
	California, Christian Church spire	100	45	10·25	·38		
	Medlock	254	50	12·26	·20		
	Moreau	304	19	34·86	·17		
36	Belshe	324	18	41·00	·17	+ ·45	41·45

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·04.

ABSTRACT OF RESULTING HORIZONTAL DIRECTIONS, OBSERVED AND ADJUSTED, AT THE STATIONS FORMING THE NET, 1879-80—completed.

High Point, Moniteau County, Missouri. July 10 to July 17, 1880. 35-centimetre theodolite, No. 10. Telescope above ground 9·69 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Correction from base-net adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
34	Christian	0	00	00·00	±0·11	−0·51	59·49
	Moreau	62	24	21·31	·17		
35	Belshe	117	56	13·80	·18	− ·35	13·45
30	Hunter (Versailles South Base)	235	44	00·73	·16	+ ·45	01·18
31	Versailles North Base	258	50	31·60	·21	+ ·65	32·25
32	Hubbard	298	10	34·62	·15	− ·92	33·70
	Tipton, First Baptist Church spire	305	18	53·98	·15		
33	Cole	310	03	36·27	·19	+ ·67	36·94
	California, Christian Church spire	353	37	15·09	·29		

Approximate probable error of a single observation of a direction (D. and R.) $= \pm 0''\cdot 99$.

Belshe, Cole County, Missouri. September 20 to October 1, 1879. 35-centimetre theodolite, No 10. Telescope above ground 9·75 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
	Moreau	0	00	00·00	±0·09		
	Medlock	17	10	49·00	·16		
	Cedar	47	47	35·48	·19		
	St. Thomas spire	98	47	48·10	·31		
	Kennedy	101	29	05·71	·18		
	Koeltztown spire	105	24	14·06	·25		
43	Hunter (Versailles South Base)	286	21	33·83	·20	+0·18	34·01
44	Versailles North Base	296	16	08·69	·15	+ ·01	08·70
45	High Point	315	25	60·07	·18	− ·62	59·45
	California spire	339	35	39·60	·38		
46	Christian	341	48	26·80	·18	+ ·44	27·24

Approximate probable error of a single observation of a direction (D. and R.) $= \pm 1''\cdot 10$.

FIGURE ADJUSTMENT.

*Observation equations.**

No.	
1	$0 = +0·20 + (1) - (7) - (14) + (17) - (22) + (23)$
2	$0 = -0·23 - (4) + (6) - (9) + (12) - (30) + (31)$
3	$0 = -1·17 - (34) + (35) - (36) + (37) - (45) + (46)$
4	$0 = +0·89 - (19) + (20) + (24) - (29) - (41) + (42)$
5	$0 = +0·10 - (2) + (4) - (25) + (27) - (31) + (33)$
6	$0 = +2·71 - (11) + (12) - (30) + (34) - (37) + (38)$
7	$0 = -0·66 - (3) + (6) - (9) + (11) - (38) + (39)$
8	$0 = -0·14 - (2) + (6) - (9) + (10) - (26) - (27)$

* Number of conditions in the net 26, of which 16 refer to sums of angles and 10 to the ratio of sides. The side equations are established with 7 places of decimals in the logarithms, and the differences for 1″ are cut off at the sixth place.

FIGURE ADJUSTMENT—continued.

Observation equations—Completed.

9 $0=-1{\cdot}83-(15)+(16)-(24)+(28)-(40)+(41)$

10 $0=-1{\cdot}34-(5)+(6)-(9)+(13)-(43)+(44)$

11 $0=-0{\cdot}48-(4)+(5)+(31)-(35)-(44)+(45)$

12 $0=+0{\cdot}75-(6)+(7)-(8)+(9)-(17)+(18)$

13 $0=-0{\cdot}34+(2)-(7)-(15)+(17)-(27)+(28)$

14 $0=-1{\cdot}25-(1)+(2)-(20)+(22)-(27)+(29)$

15 $0=+0{\cdot}19-(1)+(4)-(21)+(22)-(31)+(32)$

16 $0=+0{\cdot}702+(3)-(7)-(16)+(17)-(39)+(40)$

17 $0=-1{\cdot}3+0{\cdot}87(4)-1{\cdot}93(5)+1{\cdot}06(6)-3{\cdot}82(30)+4{\cdot}93(31)-1{\cdot}11(35)+8{\cdot}27(43)-12{\cdot}05(44)+3{\cdot}78(45)$

18 $0=-5{\cdot}7-2{\cdot}33(9)+3{\cdot}36(10)-1{\cdot}03(11)+0{\cdot}78(24)+8{\cdot}68(26)-9{\cdot}46(27)-8{\cdot}03(38)+10{\cdot}87(39)-2{\cdot}84(41)$

19 $0=-4{\cdot}54-12{\cdot}48(19)+18{\cdot}44(20)-5{\cdot}96(21)-10{\cdot}00(32)+11{\cdot}77(33)-1{\cdot}77(34)-0{\cdot}32(37)+16{\cdot}02(41)-15{\cdot}70(42)$

20 $0=-6{\cdot}1+2{\cdot}05(2)+0{\cdot}87(4)-2{\cdot}92(6)-1{\cdot}88(25)+10{\cdot}56(26)-8{\cdot}68(27)-4{\cdot}34(30)+4{\cdot}93(31)-0{\cdot}59(33)$

21 $0=-7{\cdot}6-0{\cdot}53(1)-3{\cdot}13(3)+3{\cdot}66(4)+3{\cdot}79(19)-6{\cdot}63(21)+2{\cdot}84(22)+2{\cdot}08(37)-2{\cdot}11(39)-0{\cdot}03(42)$

22 $0=-2{\cdot}2-2{\cdot}05(14)+5{\cdot}78(15)-3{\cdot}73(17)-1{\cdot}42(20)+5{\cdot}69(22)-4{\cdot}27(23)-7{\cdot}88(27)+8{\cdot}00(28)-0{\cdot}12(29)$

23 $0=-8{\cdot}6+3{\cdot}13(3)-8{\cdot}94(4)+5{\cdot}81(5)+2{\cdot}93(36)-5{\cdot}04(37)+2{\cdot}11(39)+6{\cdot}06(44)-10{\cdot}31(45)+4{\cdot}25(46)$

24 $0=-6{\cdot}2+0{\cdot}92(8)-4{\cdot}28(9)+3{\cdot}36(10)+5{\cdot}78(15)-9{\cdot}00(17)+3{\cdot}22(18)+8{\cdot}68(26)+16{\cdot}68(27)+8{\cdot}00(28)$

25 $0=+17{\cdot}6+4{\cdot}37(14)-10{\cdot}55(15)+6{\cdot}18(16)+12{\cdot}48(19)-12{\cdot}77(20)+0{\cdot}29(23)+2{\cdot}90(40)-18{\cdot}60(41)+15{\cdot}70(42)$

26 $0=-91{\cdot}7+0{\cdot}92(8)-1{\cdot}95(9)+1{\cdot}03(11)+98{\cdot}10(16)-101{\cdot}32(17)+3{\cdot}22(18)+8{\cdot}03(38)-215{\cdot}63(39)+207{\cdot}6(40)$

Correlate equations.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
(1)	+1													−1	−1	
(2)					−1			−1					+1	+1		
(3)							−1									+1
(4)		−1			+1						−1				+1	
(5)	...	...	...	...	...	...	...	...	...	−1	+1	...	...	...	...	...
(6)		+1					+1	+1		+1		−1				
(7)	−1											+4	−1			−1
(8)												−1				
(9)		−1					−1	−1		−1		+1				
(10)	...	...	...	...	...	...	...	+1	...	...	...	...	...	...	...	...
(11)						−1	+1									
(12)		+1				+1										

FIGURE ADJUSTMENT—continued.

Correlate equations—Continued.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
(13)										+1						
(14)	−1															
(15)	...	...	...	...	...	...	...	...	−1	...	...	...	−1	...	...	...
(16)									+1							−1
(17)	+1											−1	+1			+1
(18)												+1				
(19)				−1												
(20)	...	...	...	+1	...	...	...	...	...	...	...	...	...	−1	...	...
(21)															−1	
(22)	−1													+1	+1	
(23)	+1															
(24)				+1					−1							
(25)	...	...	...	...	−1	...	...	...	...	...	...	...	...	...	...	...
(26)								−1								
(27)					+1			+1					−1	−1		
(28)									+1				+1			
(29)				−1										+1		
(30)	...	−1	...	...	...	−1	...	...	...	...	...	...	...	...	...	...
(31)		+1			−1						+1				−1	
(32)															+1	
(33)					+1											
(34)			−1			+1										
(35)	...	...	+1	...	...	...	...	...	...	...	−1	...	...	...	...	...
(36)			−1													
(37)			+1			−1										
(38)						+1	−1									
(39)							+1									−1
(40)	...	...	...	...	...	...	...	...	−1	...	...	...	...	...	...	+1
(41)				−1					+1							
(42)				+1												
(43)										−1						
(44)										+1	−1					
(45)	...	...	−1	...	...	...	...	...	...	...	+1	...	...	...	...	...
(46)			+1													

Correlate equations—Continued.

Corrections.	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}
(1)					−0·53					
(2)				+ 2·05						
(3)					−3·13		+ 3·13			
(4)	+ 0·87			+ 0·87	+3·66		− 8·94			
(5)	− 1·93	....	....	....	......	......	+ 5·81	....	....	....

FIGURE ADJUSTMENT—continued.

Correlate equations—Completed.

Corrections.	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}
(6)	+ 1·06			− 2·92						
(7)										
(8)								+ 0·92		+ 0·92
(9)		− 2·33						− 4·28		− 1·95
(10)	....	+ 3·36	....	....	......	.....	....	+ 3·36	....	....
(11)		− 1·03								+ 1·03
(12)										
(13)										
(14)						−2·05			+ 4·37	
(15)	....	....	....	....	......	+5·78	....	+ 5·78	−10·55	....
(16)									+ 6·18	+ 98·10
(17)						−3·73		− 9·00		−101·32
(18)								+ 3·22		+ 3·22
(19)			−12·48		+3·79				+12·48	
(20)	....	....	+18·44	....	......	−1·42	....	....	−12·77	....
(21)			− 5·96		−6·63					
(22)					+2·84	+5·69				
(23)						−4·27			+ 0·29	
(24)		+ 0·78								
(25)	....	....	....	− 1·88	......	......	....	....	....	....
(26)		+ 8·68		+10·56				+ 8·68		
(27)		− 9·46		− 8·68		−7·88		−16·68		
(28)						+8·00		+ 8·00		
(29)						−0·12				
(30)	− 3·82	....	....	− 4·34	......	......	....	....	....	....
(31)	+ 4·93			+ 4·93						
(32)			−10·00							
(33)			+11·77	− 0·59						
(34)			− 1·77							
(35)	− 1·11	....	....	....	......	......	....	....	....	....
(36)							+ 2·93			
(37)			− 0·32		+2·08		− 5·04			
(38)		− 8·03								+ 8·03
(39)		+10·87			−2·11		+ 2·11			−215·63
(40)	....	....	....	....	......	......	....	....	− 2·90	+207·60
(41)		− 2·84	+16·02						−18·60	
(42)			−15·70		+0·03				+15·70	
(43)	+ 8·27									
(44)	−12·05						+ 6·06			
(45)	+ 3·78	....	....	....	......	......	−10·31	....	....	....
(46)							+ 4·25			

FIGURE ADJUSTMENT—continued.

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
o=+0·20	+6	...	...	...	...	...	...	...	...	...	...
−0·23		+6			−2	+2	+2	+2		+2	+2
−1·17			+6			−2					−2
+0·89				+6					−2		
+0·10	...	...	...	...	+6	...	...	+2	...	...	−2
+2·71						+6	−2				
−0·66							+6	+2		+2	
−0·14								+6		+2	
−1·83									+6		
−1·34	...	...	...	...	...	...	...	...	...	+6	−2
−0·48											+6

Normal equations—Continued.

	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}
+ 0·20	−2	+2	−2	−2	+2	....	....	....
− 0·23	−2			−2		+ 8·94	+ 2·33	
− 1·17						− 4·89		+ 1·45
+ 0·89			−2				+ 3·62	− 0·80
+ 0·10	...	−2	−2	+2	...	− 4·06	− 9·46	+11·77
+ 2·71						+ 3·82	− 7·00	− 1·45
− 0·66	−2				−2	+ 1·06	+20·20	
− 0·14	−2	−2	−2			+ 1·06	−12·45	
− 1·83		+2			−2		− 3·62	+16·02
− 1·34	−2	...	...	...	...	−17·33	+ 2·33	....
− 0·48				−2		+19·07		
o=+ 0·75	+6	−2			−2	− 1·06	− 2·33	
− 0·34		+6	+2		+2		+ 9.46	
− 1·25			+6	+2			+ 9·46	−18·44
+ 0·19	...	...	...	+6	...	− 4·06	....	− 4·04
+ 0·702					+6		−10·87	
− 1·3						+273·619		
− 5·7							+373·925	−45·497
−45·4								+1 276·204

FIGURE ADJUSTMENT--completed.

Normal equations—Completed.

	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}
+ 0·20	....	− 3·37	−11·64	....	− 9·00	− 4·08	−101·32
− 0·23	+5·48	− 3·66		+ 8·94	+ 4·28		+ 1·95
− 1·17		+ 2·08		+ 6·59			
+ 0·89		− 3·76	− 1·30			+ 9·05	
+ 0·10	−13·50	+ 3·66	− 7·88	− 8·94	−16·68	....	....
+ 2·71	+ 4·34	− 2·08		+ 5·04			+ 7·00
− 0·66	− 2·92	+ 1·02		− 1·02	+ 4·28		−220·68
− 0·14	−24·21		− 7·88		−17·72		+ 1·95
− 1·83			+ 2·22		+ 2·22	− 4·77	−109·50
− 1·34	− 2·92	....	......	+ 0·25	+ 4·28	....	+ 1·95
− 0·48	+ 4·06	− 3·66		− 1·62			
+ 0·75	+ 2·92		+ 3·73		+ 7·02		+101·67
− 0·34	+10·73		+ 6·37		+ 9·90	+ 10·55	−101·32
− 1·25	+10·73	+ 3·37	+14·87		+16·68	+ 12·77	
+ 0·19	− 4·06	+13·66	+ 5·69	− 8·94	....	....	....
+ 0·702		− 1·02	− 3·73	+ 1·02	− 9·00	− 3·28	+223·81
− 1·3	+38·545	+ 3·184		−130·986			
− 5·7	+173·774	−22·936	+74·545	+22·936	+254·397	+ 52·824	−2 404·896
−45·4	− 6·944	− 8·921	−26·185	+ 1·613		−935·691	
0=− 6·1	+247·365	+ 3·184	+68·398	− 7·778	+236·443	....	....
− 7·6		+98·639	+16·160	−57·453		+ 47·770	+454·979
− 2·2			+230·258		+262·417	− 53·052	+377·924
− 8·6				+322·997			−454·979
− 6·2					+572·796	− 60·979	+931·441
+17·6	....	....	....	....	....	+1 088·359	+1 208·298
−91·7							+109 563·968

Resulting values of correlates and of corrections to angular directions.

CORRELATES.

C_1=+0·198 7	C_8=+0·016 9	C_{15}=−0·825 8	C_{21}=+0·259 14
C_2=−0·217 3	C_9=+0·617 2	C_{16}=−0·113 3	C_{22}=−0·028 55
C_3=−0·088 0	C_{10}=+0·792 6	C_{17}=+0·117 13	C_{23}=+0·124 43
C_4=+0·562 2	C_{11}=+0·129 0	C_{18}=+0·090 58	C_{24}=−0·022 55
C_5=+0·543 3	C_{12}=−0·132 8	C_{19}=+0·009 52	C_{25}=−0·040 16
C_6=−0·577 8	C_{13}=−0·292 5	C_{20}=−0·024 39	C_{26}=+0·002 686 4
C_7=−0·608 0	C_{14}=+1·024 8		

Resulting values of correlates and of corrections to angular directions—Completed.

CORRECTIONS.

″	″	″	″
(1)=−0·137 7	(13)=+0·792 6	(25)=−0·497 5	(36)=+0·452 6
(2)=+0·122 1	(14)=−0·315 7	(26)=+0·316 0	(37)=+0·398 6
(3)=+0·072 1	(15)=−0·196 4	(27)=−0·216 0	(38)=+0·675 7
(4)=−0·277 5	(16)=+0·746 0	(28)=−0·084 0	(39)=−0·372 6
(5)=−0·166 8	(17)=−0·036 9	(29)=+0·466 0	(40)=−0·289 2
(6)=+0·312 3	(18)=−0·197 0	(30)=+0·453 6	(41)=+0·697 2
(7)=+0·074 3	(19)=−0·200 0	(31)=+0·651 4	(42)=−0·210 0
(8)=+0·114 5	(20)=+0·266 3	(32)=−0·921 0	(43)=+0·176 1
(9)=−0·236 8	(21)=−0·949 1	(33)=+0·669 8	(44)=+0·006 2
(10)=+0·245 4	(22)=+0·573 8	(34)=−0·506 6	(45)=−0·623 1
(11)=−0·120 7	(23)=+0·309 0	(35)=−0·347 0	(46)=+0·440 8
(12)=−0·795 1	(24)=+0·015 7		

CHECK.

$\Sigma pvv = 8 \cdot 931\ 7$
$-[wC] = 8 \cdot 932\ 7$

CHECK.

Σ of + corrections = 8·372 4
Σ of − corrections = 8·372 4

Mean error of an observed direction $m_1 = \sqrt{\frac{[pvv]}{n}} = \pm 0''.59$ where $n =$ number of conditions.
Mean error of an angle $m_{\angle} = m_1 \sqrt{2} = \pm 0.83$; also probable error of the same $= \pm 0''.56$.

TRIANGLES OF THE VERSAILLES BASE NET, MISSOURI, 1879–1880.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distance in metres.
		°	′	″	″	″	″		
1	Hughes	33	10	50·59	−0·16	50·43	0·08	3·883 312 3	7 643·852
	Versailles North Base	80	28	22·95	−0·24	22·71	0·08	4·139 070 5	13 774·33
	Hunter	66	20	47·45	−0·35	47·10	0·08	4·106 991 9	12 793·58
				00·99			0·24		
2	Cole	13	37	32·17	−0·53	31·64	0·08	3·883 312 3	7 643·852
	Hunter	32	02	47·08	+0·48	47·56	0·08	4·235 959 3	17 217·07
	Versailles North Base	134	19	40·85	+0·19	41·04	0·08	4·365 704 8	23 211·58
				00·10			0·24		
3	Cole	28	22	52·82	−0·40	52·42	0·26	4·139 070 5	13 774·33
	Hunter	98	23	34·53	+0·13	34·66	0·27	4·457 394 6	28 667·82
	Hughes	53	13	33·72	0·00	33·72	0·27	4·365 704 8	23 211·58
				01·07			0·80		
4	Cole	14	45	20·65	+0·13	20·78	0·10	4·106 991 9	12 793·58
	Versailles North Base	145	11	56·20	+0·05	56·25	0·11	4·457 394 6	28 667·82
	Hughes	20	02	43·13	+0·16	43·29	0·11	4·235 959 2	17 217·07
				59·98			0·32		
5	Hubbard	55	58	59·68	+0·31	59·99	0·18	4·235 959 3	17 217·07
	Cole	86	48	07·58	+0·68	08·26	0·19	4·316 793 9	20 739·29
	Versailles North Base	37	12	52·04	+0·26	52·30	0·18	4·099 082 7	12 562·69
				59·30			0·55		

TRIANGLES OF THE VERSAILLES BASE NET, MISSOURI, 1879-1880—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log s.	Distance in metres.
		°	′	″	″	″	″		
6	Hubbard	82	13	13·27	+0·04	13·31	0·29	4·457 394 6	28 667·82
	Cole	72	02	46·93	+0·55	47·48	0·29	4·439 731 0	27 525·23
	Hughes	25	43	59·96	+0·12	60·08	0·29	4·099 082 6	12 562·69
				00·16			0·87		
7	Hubbard	26	14	13·59	−0·27	13·32	0·21	4·106 991 9	12 793·58
	Versailles North Base	107	59	04·16	−0·21	03·95	0·22	4·439 731 1	27 525·24
	Hughes	45	46	43·09	+0·28	43·37	0·21	4·316 793 9	20 739·29
				00·84			0·64		
8	High Point	23	06	30·87	+0·20	31·07	0·12	3·883 312 3	7 643·852
	Hunter	89	29	18·05	−0·56	17·49	0·12	4·289 482 7	19 475·23
	Versailles North Base	67	24	11·20	+0·59	11·79	0·11	4·254 811 0	17 980·88
				00·12			0·35		
9	High Point	74	19	35·54	+0·22	35·76	0·30	4·365 704 8	23 211·58
	Hunter	57	26	30·97	−1·04	29·93	0·30	4·307 907 8	20 319·26
	Cole	48	13	54·39	+0·81	55·20	0·29	4·254 810 9	17 980·88
				00·90			0·89		
10	High Point	39	20	03·02	−1·57	01·45	0·33	4·316 793 9	20 739·29
	Versailles North Base	104	08	21·69	−0·14	21·55	0·33	4·501 457 2	31 729·06
	Hubbard	36	31	36·47	+1·52	37·99	0·33	4·289 482 9	19 475·24
				01·18			0·99		
11	High Point	51	13	04·67	+0·02	04·69	0·26	4·235 959 3	17 217·07
	Versailles North Base	66	55	29·65	−0·40	29·25	0·26	4·307 907 8	20 319·26
	Cole	61	51	26·56	+0·28	26·84	0·26	4·289 482 8	19 475·24
				00·88			0·78		
12	High Point	11	53	01·65	+1·59	03·24	0·11	4·099 082 7	12 562·69
	Hubbard	19	27	23·21	−1·21	22·00	0·12	4·307 907 8	20 319·26
	Cole	148	39	34·14	+0·96	35·10	0·11	4·501 457 1	31 729·05
				59·00			0·34		
13	Christian	30	12	30·25	−1·08	29·17	0·19	4·254 811 0	17 980·88
	High Point	124	15	59·27	−0·96	58·31	0·20	4·470 327 7	29 534·37
	Hunter	25	31	33·77	−0·67	33·10	0·19	4·187 515 2	15 399·80
				03·29			0·58		
14	Christian	44	54	30·92	−0·77	30·15	0·25	4·289 482 8	19 475·24
	High Point	101	09	28·40	−1·15	27·25	0·25	4·432 406 7	27 064·92
	Versailles North Base	33	56	03·70	−0·35	03·35	0·35	4·187 515 1	15 399·80
				03·02			0·75		

TRIANGLES OF THE VERSAILLES BASE NET, MISSOURI, 1879–1880—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distance in metres.
		°	′	″	″	″	″		
15	Christian	81	30	23·13	+0·30	23·43	0·21	4·307 907 8	20 319·26
	High Point	49	56	23·73	−1·18	22·55	0·20	4·196 566 4	15 724·12
	Cole	48	33	15·14	−0·51	14·63	0·20	4·187 515 2	15 399·80
				02·00			0·61		
16	Christian	89	08	40·05	−0·61	39·44	0·37	4·501 457 2	31 729·06
	High Point	61	49	25·38	+0·41	25·79	0·36	4·446 727 5	27 972·26
	Hubbard	29	01	56·61	−0·75	55·86	0·36	4·187 515 2	15 399·80
				02·04			1·09		
17	Christian	14	42	00·67	+0·30	00·97	0·17	3·883 312 3	7 643·852
	Hunter	63	57	44·28	+0·12	44·40	0·17	4·432 406 9	27 064·93
	Versailles North Base	101	20	14·90	+0·24	15·14	0·17	4·470 327 7	29 534·37
				59·85			0·51		
18	Christian	15	16	52·58	+0·39	52·97	0·26	4·139 070 5	13 774·33
	Hunter	130	18	31·73	−0·23	31·50	0·27	4·600 473 6	39 854·16
	Hughes	34	24	37·26	−0·94	36·32	0·26	4·470 327 7	29 534·37
				01·57			0·79		
19	Christian	51	17	52·88	+1·37	54·25	0·31	4·365 704 8	23 211·58
	Hunter	31	54	57·20	−0·36	56·84	0·30	4·196 566 3	15 724·12
	Cole	96	47	09·53	+0·30	09·83	0·31	4·470 327 6	29 534·36
				59·61			0·92		
20	Christian	0	34	51·91	−0·083	51·993	0·009	4·106 991 9	12 793·58
	Versailles North Base	178	11	22·15	−0·002	22·148	0·009	4·600 473 7	39 854·17
	Hughes	1	13	46·67	−0·783	45·887	0·010	4·432 406 9	27 064·93
				00·73			0·028		
21	Christian	36	35	52·21	+1·07	53·28	0·21	4·235 959 3	17 217·07
	Versailles North Base	32	59	25·95	−0·05	25·90	0·21	4·196 566 4	15 724·12
	Cole	110	24	41·70	−0·24	41·46	0·22	4·432 406 8	27 064·92
				59·86			0·64		
22	Christian	44	14	09·13	+0·16	09·29	0·44	4·316 793 9	20 739·29
	Versailles North Base	70	12	17·99	+0·21	18·20	0·45	4·446 727 6	27 972·26
	Hubbard	65	33	33·08	+0·77	33·85	0·45	4·432 406 9	27 064·93
				00·20			1·34		
23	Christian	36	01	00·30	+0·99	01·29	0·31	4·457 394 6	28 667·82
	Hughes	18	48	56·46	+0·94	57·40	0·31	4·196 566 3	15 724·12
	Cole	125	10	02·35	−0·10	02·25	0·32	4·600 473 6	39 854·16
				59·11			0·94		

TRIANGLES OF THE VERSAILLES BASE NET, MISSOURI, 1879–1880—completed.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distance in metres.
		°	′	″	″	″	″		
24	Christian	43	39	17 ·22	+0 ·08	17 ·30	0 ·65	4 ·439 731 1	27 525 ·24
	Hughes	44	32	56 ·42	+1 ·06	57 ·48	0 ·65	4 ·446 727 5	27 972 ·26
	Hubbard	91	47	46 ·67	+0 ·50	47 ·17	0 ·65	4 ·600 473 7	39 854 ·17
				00 ·31			1 ·95		
25	Christian	7	38	16 ·92	−0 ·91	16 ·01	0 ·05	4 ·099 082 7	12 562 ·69
	Cole	162	47	10 ·72	−0 ·45	10 ·27	0 ·05	4 ·446 727 5	27 972 ·26
	Hubbard	9	34	33 ·40	+0 ·47	33 ·87	0 ·05	4 ·196 566 4	15 724 ·12
				01 ·04			0 ·15		
26	Belshe	9	54	34 ·86	−0 ·17	34 ·69	0 ·18	3 ·883 312 3	7 643 ·852
	Hunter	122	37	04 ·11	+1 ·03	05 ·14	0 ·18	4 ·573 004 7	37 411 ·47
	Versailles North Base	47	28	20 ·23	+0 ·48	20 ·71	0 ·18	4 ·514 985 7	32 732 ·99
				59 ·20			0 ·54		
27	Belshe	29	04	26 ·24	−0 ·80	25 ·44	0 ·27	4 ·254 811 0	17 980 ·88
	Hunter	33	07	46 ·06	+1 ·59	47 ·65	0 ·28	4 ·305 854 4	20 223 ·41
	High Point	117	47	46 ·93	+0 ·80	47 ·73	0 ·27	4 ·514 985 6	32 732 ·98
				59 ·23			0 ·82		
28	Belshe	55	26	52 ·97	−0 ·26	53 ·23	0 ·70	4 ·470 327 7	29 534 ·37
	Hunter	58	39	19 ·83	+0 ·92	20 ·75	0 ·70	4 ·486 091 7	30 626 ·10
	Christian	65	53	49 ·25	−1 ·13	48 ·12	0 ·70	4 ·514 985 6	32 732 ·98
				02 ·05			2 ·10		
29	Belshe	19	09	51 ·38	−0 ·63	50 ·75	0 ·21	4 ·289 482 8	19 475 ·24
	Versailles North Base	19	55	50 ·97	+0 ·11	51 ·08	0 ·21	4 ·305 854 3	20 223 ·40
	High Point	140	54	17 ·80	+1 ·00	18 ·80	0 ·21	4 ·573 004 5	37 411 ·45
				00 ·15			0 ·63		
30	Belshe	45	32	18 ·11	+0 ·44	18 ·55	0 ·69	4 ·432 406 8	27 064 ·92
	Versailles North Base	53	51	54 ·67	−0 ·24	54 ·43	0 ·69	4 ·486 091 7	30 626 ·10
	Christian	80	35	49 ·92	−0 ·82	49 ·10	0 ·70	4 ·573 004 5	37 411 ·45
				02 ·70			2 ·08		
31	Belshe	26	22	26 ·73	+1 ·06	27 ·79	0 ·24	4 ·187 515 2	15 399 ·80
	High Point	117	56	13 ·80	+0 ·16	13 ·96	0 ·23	4 ·486 091 6	30 626 ·09
	Christian	35	41	19 ·00	−0 ·05	18 ·95	0 ·23	4 ·305 854 2	20 223 ·40
				59 ·53			0 ·70		

PROBABLE ERRORS.

Determination of the probable errors of the length of the sides of the base net making the connection with the adjacent chains of triangulation.

The side Christian to Belshe is connected with the base by the equation—

$$\frac{\text{Christian to Belshe}}{\text{Versailles Base}} = \frac{\sin(13-11)\sin(6-3)}{\sin(46-43)\sin 39-38)}$$

Hence the function—

$$F = \log\sin(13-11) + \log\sin(6-3) - \log\sin(46-43) - \log\sin(39-38)$$

Establishing and solving the transfer equations, we find for the reciprocal of the weight or $\frac{1}{p} = 16{\cdot}66$; also the mean error m_F and the probable error r_F, both expressed in units of the sixth place of decimals of the logarithm, viz: $m_F = \pm 2{\cdot}39$ and $r_F = \pm 1{\cdot}61$; hence log. distance Christian to Belshe $\underset{\pm 1\ 6}{4{\cdot}486\ 091\ 7}$ and the distance $\underset{\pm\ 11}{30\ 626{\cdot}10}$ metres. The probable error is about $\frac{1}{270\ 000}$ of the length.

To this must be added the uncertainty due to the base measure or—

$$\pm 0{\cdot}008 \times \frac{30\ 626}{7\ 644} = \pm 0{\cdot}032.$$

Then total probable error of side Christian to Belshe—

$$\sqrt{({\cdot}11)^2 + (0{\cdot}032)^2} = \pm 0{\cdot}12 \text{ metre.}$$

The side Hubbard to Hughes is connected with the base by the equation—

$$\frac{\text{Hubbard to Hughes}}{\text{Versailles Base}} = \frac{\sin(1-7)\sin(9-8)}{\sin(23-22)\sin(18-17)}$$

Take the function $F = \log\sin(1-7) + \log\sin(9-8) - \log\sin(23-22) - \log\sin(18-17)$, then $\frac{1}{p} = 9{\cdot}97$ and $m_F = \pm 1{\cdot}85$ and $r_F = \pm 1{\cdot}25$; hence log. distance Hubbard to Hughes $\underset{\pm\ \ 1\ 2}{4{\cdot}439\ 731\ 1}$ and length of side $= \underset{\pm\ 08}{27\ 525{\cdot}24}$ metres. The probable error is about $\frac{1}{344\ 000}$ part of the length.

Adding to this the uncertainty arising from that of the base or—

$$\pm 0{\cdot}008 \times \frac{27\ 525}{7\ 644} = \pm 0{\cdot}022,$$

we have for the probable error of the length of side Hubbard to Hughes—

$$\sqrt{({\cdot}08)^2 + (0{\cdot}022)^2} = \pm 0{\cdot}08 \text{ metre.}$$

Similarly we obtain the probable error of the side Christian to High Point—

$$\sqrt{({\cdot}053)^2 + ({\cdot}016)^2} = \pm 0{\cdot}06 \text{ metre.}$$

Also probable error of side High Point to Belshe—

$$\sqrt{({\cdot}07)^2 + ({\cdot}021)^2} = \pm 0{\cdot}08 \text{ metre.}$$

GENERAL DESCRIPTION OF STATIONS FORMING THE VERSAILLES BASE NET, MISSOURI.

Versailles North Base, Morgan County; established by J. A. Sullivan in 1878. This station is situated about 5 miles north-northeast of Versailles, in the southern part of the west half of the southwest quarter of section 9, township 43 north, range 17 west of the fifth principal meridian, on land owned by Moses H. Tipton.

The geodetic point is marked by the intersection of cross lines on a copper bolt, set in the top of a rough-dressed sandstone block, 11 inches square and 21¼ inches long, set in cement and concrete 20 inches below the surface of the ground.

The surface mark is a block of similar stone, 25½ inches square and 10½ inches thick, set in concrete and cement directly over the subsurface mark. It bears the inscription "U.S.C.& G.S. 1897," cut on its top surface, and has a copper bolt and cross lines in the center.

As reference marks, two stone posts, 5 inches square and marked with a single cross line and arrowhead pointing toward the station, were set, one north and one south, each 5 feet distant from the geodetic point.

Hunter-Versailles South Base, Morgan County; established by J. A. Sullivan in 1878. This station is situated 4 miles east of Versailles, in Moreau Township. It is in the southeast half of the southwest quarter of section 2, township 42 north, range 17 west of the fifth principal meridian, on land owned (1897) by the estate of D. C. Dale. The geodetic point is marked by the intersection of cross lines on a copper bolt set in the top of a rough-dressed sandstone block, 11 inches square and 21¼ inches long, set in concrete and cement 13½ inches below the surface of the ground. The surface mark is a block of similar stone, 25½ inches square and 9½ inches thick, set in concrete and cement directly over the subsurface mark, with a copper bolt and cross lines in the center, and having the inscription "U.S.C.& G.S. 1897," cut on its top surface. As reference marks, two stone posts, 5 inches square and marked with a single cross line and arrowhead pointing toward the station, were set, one north and one south, each 5 feet distant from the geodetic point.

Hughes, Morgan County; established by J. A. Sullivan in 1878. This station is situated about 5 miles nearly due west of Versailles, on the Warsaw road. It is near the center of section 5, township 42 north, range 18 west of the fifth principal meridian, on land owned by Mr. Robert Hughes.

The geodetic point is marked underground by a bottle filled with ashes and buried 2 feet 6 inches below the surface. The surface mark is a stone post 6 inches square and 2 feet long, marked with two rectangular grooves and the letters U.S.C.S. As reference marks, two stone posts, 5 inches square and marked with a single cross line and arrowhead pointing toward the station, were set, one north and one south, each 5 feet distant from the geodetic point.

Cole, Moniteau County; established by J. A. Sullivan in 1879. This station is situated about 3 miles east-southeast of Tipton and is known as the "Old Windmill," on land owned by Mrs. S. F. Cole. It is in the northern part of section 30, township 45 north, range 16 west of the fifth principal meridian. The geodetic point is marked underground by a bottle filled with ashes, over which was placed as a surface mark a stone post, 6 inches square and 2 feet long, marked on the top with two rectangular grooves and the letters U.S.C.S. As reference marks, two stone posts, 5 inches square

and marked with a single cross line and arrowhead pointing toward the station, were set, one north and one south, each 4 feet distant from the geodetic point.

Hubbard, Morgan County; established by J. A. Sullivan in 1878. This station is situated about three-fourths mile northeast of Syracuse, on land owned by Mr. Joel Hubbard. It is near the center of the southeast quarter of section 11, township 45 north, range 18 west of the fifth principal meridian. The geodetic point is marked underground by a bottle filled with ashes, over which was placed as a surface mark a stone post, 6 inches square and 2 feet long, marked on the top with two rectangular grooves and the letters U.S.C.S. As reference marks, two stone posts were set, 5 inches square and marked with a single cross line and arrowhead, pointing toward the station, one north and one south, each 5 feet distant from the geodetic point.

Christian, Moniteau County; established by J. A. Sullivan in 1878. This station is situated about a mile east-southeast of the court-house, in the town of California, on land belonging to the minor heirs of J. J. Christian. It is just east of the center of the southern edge of the northeast quarter of section 27, township 45 north, range 15 west of the fifth principal meridian, on a narrow strip of land—an open field—between the Missouri Pacific Railroad and the "State road," from Jefferson City; about 75 yards south of the former and about 40 north of the latter. The Christian house, a two-story brick, is about 300 yards east-northeast, and the house of H. Boepler about 150 yards southwest of the station. The geodetic point is marked underground by a bottle filled with ashes, over which was placed as a surface mark a stone post, 6 inches square and 2 feet long, marked on the top with two rectangular grooves and the letters U.S.C.S. As reference marks, two stone posts were set, 5 inches square, and marked with a single cross line and arrowhead, pointing toward the station, one north and one south, each 5 feet distant from the station point.

High Point, Moniteau County; established by J. A. Sullivan in 1878. This station is situated one-half mile northeast of the village of High Point, in the southern part of Moniteau County; near the middle of the southern edge of the western half of section 9, township 43 north, range 15 west of the fifth principal meridian, on land belonging to the undivided estate of George Radcliff, sr. The nearest railroad station is California, on the Missouri Pacific Railroad, distant 12 miles, nearly due north. The geodetic point is marked underground by a bottle filled with ashes, over which as a surface mark was placed a stone post, 6 inches square and 2 feet long, marked on the top with two rectangular grooves and the letters U.S.C.S. As reference marks, two stone posts, 5 inches square and marked with a single diagonal groove and arrowhead, pointing toward the station, were set, one north and one south, each 5 feet distant from the geodetic point.

Belshe, Cole County; established by J. A. Sullivan in 1878. This station is situated in the southwest part of Cole County, on the road from Jefferson City to Tuscumbia, Miller County, and about 50 yards east of the line between Cole and Miller counties. It is 1 mile southeast of Spring Garden Hill and about one-half mile northeast of Locust Mound post-office, Miller County. The nearest railroad station is Centertown, on the Missouri Pacific Railroad, distant 19 miles, nearly due north. It is near the center of the north half of the southwest fractional quarter of section 19, township 42 north, range 13 west of the fifth principal meridian; in the yard of August Pfitzer's house, and 26·1 feet from the northeast corner. The geodetic point is marked

underground by a bottle filled with ashes, over which was placed as a surface mark a stone post, 6 inches square and 2 feet long, marked on the top with two rectangular grooves and the letters U.S.C.S. As reference marks, two stone posts, 5 inches square and marked with a single diagonal groove and arrowhead, pointing toward the station, were set, one north and one south, each 5 feet distant from the geodetic point.

(3.) SYNOPSIS OF FACTS AND RESULTS RELATIVE TO PRECEDING BASE LINES AND BASE NETS.

[The bases are given here in their geographic order from east to west.]

Preceding No. of base.	Name of base.	State.	Height above ocean.	Approximate length of base in statute miles.	Length of base and probable error.	Probable error in parts of the base.	Logarithm of length of base.	Number of stations in net.	Number of conditions in net.	Mean error of an observed horizontal angle.
			m.		m.					″
1	Kent Island	Maryland	5	5·398	8 687·544 6 ±68 0	1/128 000*	3·938 897 05 ± 3 40	9	13	±0·87
7	St. Albans	West Virginia	180	2·405	3 870·402 8 ± 3 5	1/1 106 000	3·587 756 17 ± 39	13	30	±0·98
6	Holton	Indiana	284	3·418	5 500·570 0 ± 4 0	1/1 375 000	3·740 407 70 ± 32	9	15	·0·71
3	Olney	Illinois	148	4·095	6 590·780 4 ± 8 9	1/740 000	3·818 936 84 ± 59	11	32	±0·61
2	American Bottom	Illinois	133	4·515	7 266·883 7 ±20 6	1/353 000*	3·861 348 21 ± 1 23	8	16	±1·72
10	Versailles	Missouri	311	4·750	7 643·852 5 ± 8 0	1/955 000	3·883 312 30 ± 46	8	26	±0·83
8	Salina	Kansas	370	4·071	6 552·446 2 ± 6 3	1/1 040 000	3·816 403 46 ± 42	7	13	±0·92
4	El Paso	Colorado	2 063	7·015	11 289·176 4 ±15 0	1/753 000	4·052 662 26 ± 58	6	14	±0·84
9	Salt Lake	Utah	1 297	6·958	11 198·676 9 ± 7 0	1/1 600 000	4·049 166 72 ± 27	10	30	±0·67
5	Yolo	California	27	10·866	17 486·511 9 ±16 3	1/1 073 000	4·242 703 19 ± 40	7	17	±0·51
		Sum		53·491	86·086 km.			88	206	

* The probable error is to a great extent estimated.

PART II.

DETERMINATION OF HEIGHTS OF STATIONS.

CONTENTS OF PART II.

II. DETERMINATION OF HEIGHTS OF STATIONS.

(A) GENERAL REMARKS.

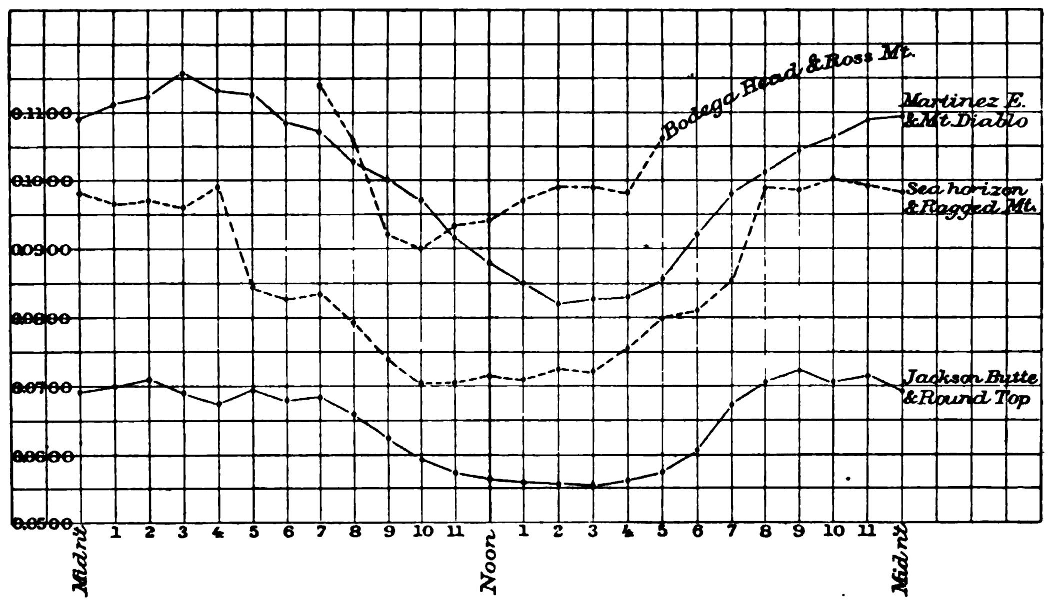
The necessity of determining the elevations of points in the triangulation is apparent from what has been stated. These elevations were required in the preceding part in connection with base lines, whose lengths had to be referred to the same level, i. e., to the equipotential surface or an imagined continuation of the average level of the ocean. Besides, the elevations of the stations located at the higher levels must be known, at least approximately, in order to reduce the horizontal angle measures to what they would have been if the stations *observed upon* had been at the sea level. This reduction is ordinarily but a small fraction of a second of arc, but in refined work can not be ignored. Lastly, from a geographic point of view the third or height coordinate of points in the triangulation should be determined. There are, however, only certain parts of the triangulation presenting special features, for which it is desirable here to furnish detailed information. For the foundation of the hypsometric measures in the eastern part of the Survey we have a continuous line of spirit levels run between the years 1878–1898, commencing at the Atlantic coast, with its principal terminus at Sandy Hook, New Jersey, and its two southerly connections with tidewater at the Gulf and extending to the eastern flank of the Rocky Mountains at Colorado Springs, Colorado.* With this line occasional connections were made for height of points of the triangulation, though in general but few observations for determining the height of triangulation stations were made until "First View," Colorado, was reached. From that station we have a continuous and complete series of observations of zenith distances, or of micrometric differences of height to carry the height determinations to "Mount Diablo" and "Ross Mountain," in California. These two stations were connected by spirit levels with the Pacific Ocean. It is contemplated, ultimately, to carry the line of spirit levels from ocean to ocean, but in order not to delay the computation and publication of the results of the triangulation it was thought expedient and sufficient to depend for heights upon the measures of zenith distances between the stations stretching from Pikes Peak to the California Coast Range.

The determination of heights from zenith distances and from micrometric measures of difference of height will be presented under the following heads: The heights of principal trigonometric stations in eastern Colorado between First View and Pikes Peak; the heights of the subordinate trigonometric stations in the vicinity of the Coast Range of California from Point Arena to the Yolo Base; the heights of primary trigonometric stations on the Sierra Nevada, California, from measures in and across the

*The results of these leveling operations will be found in Appendix 11, Report for 1882; Appendix 14, Report 1887; Appendix 15, Report 1889; Appendix 2, Report 1893; Appendixes 2, 3, 4, and 5, Report 1896; Appendix 4, Report 1897; and Appendixes 1, 2, and 3, Report 1898.

Sacramento and San Joaquin Valleys; the heights of the primary trigonometric stations in Nevada, Utah, and Colorado, between the Sierra Nevada and the eastern bank of the Rocky Mountains near Pikes Peak. For these several regions full information will be given as to abstracts of resulting zenith distances at each station, with adjustment of the individual differences of height and final results. For other localities where heights are desired the results are simply stated.

No. 15.



Besides the measures of zenith distances and micrometric differences of height mentioned above, three series of special hourly observations, continued for a number of days, were made for the purpose of elucidating the law of the diurnal variation of the atmospheric refraction and consequent variation of the deduced difference of height. The *first series* comprises reciprocal observations at Bodega Head and Ross Mountain, California, made on 6 days in March, 1860, from 7th hour a. m. to 5th hour p. m. For record and discussion see Appendix No. 16, Coast Survey Report for 1876. The *second series* comprises reciprocal observations at Martinez East and Mount Diablo, California, made on 14 days in March and April, 1880, hourly from midnight to midnight. For record and discussion see Appendix No. 12, Goast and Geodetic Survey Report for 1883. The *third series* comprises reciprocal observations at Jackson Butte and Round Top, California, made hourly on 14 days in September and October, 1879. All three series were made under the direction of Assistant G. Davidson. This last series was discussed and made ready for printing by the writer in 1884, but publication was delayed in the hope of having supplied a line of spirit levels between the two stations. This paper will be found appended to the present discussion.

For the sake of easy reference, we shall give here in tabular form and also exhibit by diagrams the resulting hourly values of the coefficient of refraction,* m, from four experimental series—i. e., the three referred to and a fourth which comprises observations of the zenith distance of the sea level. These were made at Ragged Mountain,

* Usually denoted by k, but in the Coast and Geodetic Survey papers the designation m ($= \frac{1}{2}k$) has been adopted.

on the coast of Maine, by Assistant F. W. Perkins on 27 days at irregular hours, but mostly between 6th hour a. m. and 6th hour p. m. in July, August, and September. (See Appendix No. 17, Report for 1876.) The line Bodega Head to Ross Mountain is directly on the Pacific coast, part of the line passing over the ocean; its length is 22·48 kilometres. The line Martinez East to Mount Diablo, although 50 kilometres (31 statute miles) inland, is still under the direct influence of the winds from the Pacific; its length is 24·26 kilometres. The line Jackson Butte to Round Top, about 200 kilometres (124 miles) from the coast, is affected by the climatic conditions of the valley; its length is 72·37 kilometres. The elevations of the two stations for these lines are 73 and 672 metres, 57 and 1 173 metres, and 714 and 3 174 metres, respectively. The height of Ragged Mountain is 397 metres. The tabular values were deduced under the supposition of equal refraction angles at lower and upper stations.

1. HOURLY VALUES OF THE COEFFICIENT OF REFRACTION (m) FROM SPECIAL OBSERVATIONS OVER FOUR LINES IN CALIFORNIA AND MAINE.

Local hour.	Bodega Head and Ross Mountain.	Martinez East and Mount Diablo.	Jackson Butte and Round Top.	Sea Horizon and Ragged Mountain.
Midnight	....	0·109 2	0·069 4	0·098 0
1 a. m.	....	·111 3	·070 0	·096 2
2	....	·112 0	·071 1	·097 2
3	....	·115 5	·068 9	·095 9
4	....	·113 1	·067 8	·099 0
5	....	·112 6	·069 7	·084 6
6	....	·108 5	·068 0	·082 8
7	0·114	·107 1	·068 4	·083 6
8	·106	·102 7	·066 2	·079 6
9	·092	·100 3	·062 7	·073 9
10	·090	·097 0	·059 8	·070 6
11	·093	·091 5	·057 4	·070 7
Noon	·094	·088 1	·056 4	·071 3
1 p. m.	·097	·085 0	·056 0	·070 9
2	·099	·082 2	·055 7	·072 5
3	·099	·082 5	·055 7	·072 2
4	·098	·083 0	·056 1	·075 3
5	0·106	·085 5	·057 7	·079 9
6	....	·092 0	·060 6	·081 0
7	....	·098 3	·067 7	·085 3
8	....	·101 2	·070 5	·099 1
9	....	·104 6	·072 5	·098 9
10	...	·106 3	·070 5	·099 9
11	....	·109 0	·071 9	·099 6
Midnight	....	0·109 2	0·069 4	0·098 0
Daily mean		0·100 0	0·064 6	0·084 9

2. DIURNAL VARIATION OF COEFFICIENT OF REFRACTION.

Local hour.	Martinez East and Mount Diablo.	Jackson Butte and Round Top.	Sea Horizon and Ragged Mountain.
Midnight	+0·009 2	+0·004 8	+0·013 1
1 a. m.	+ ·011 3	+ ·005 4	+ ·011 3
2	+ ·012 0	− ·006 5	+ ·012 3
3	+ ·015 5	+ ·004 3	+ ·011 0
4	+ ·013 1	+ ·003 2	+ ·014 1
5	+ ·012 6	+ ·005 1	− ·000 3
6	+ ·008 5	+ ·003 4	− ·002 1
7	+ ·007 1	+ ·003 8	− ·001 3
8	+ ·002 7	+ ·001 6	− ·005 3
9	+ ·000 3	− ·001 9	− ·011 0
10	− ·003 0	− ·004 8	− ·014 3
11	− ·008 5	− ·007 2	− ·014 2
Noon	− ·011 9	− ·008 2	− ·013 6
1 p. m.	− ·015 0	− ·008 6	− ·014 0
2	− ·017 8	− ·008 9	− ·012 4
3	− ·017 5	− ·008 9	− ·012 7
4	− ·017 0	− ·008 5	− ·009 6
5	− ·014 5	− ·006 9	− ·005 0
6	− ·008 0	− ·004 0	− ·003 9
7	− ·001 7	+ ·003 1	+ ·000 4
8	+ ·001 2	+ ·005 9	+ ·014 2
9	+ ·004 6	+ ·007 9	+ ·014 0
10	+ ·006 3	+ ·005 9	+ ·015 0
11	+ ·009 0	+ ·007 3	+ ·014 7
Midnight	+ ·009 2	+ ·004 8	+ ·013 1
Daily range	0·033 3	0·016 8	0·029 3

Maximum and minimum values of the hourly variation of *m* are underlined. The hourly values for the four localities are plotted in the accompanying diagram (No. 15). It shows that the refraction is greater and more irregular during the night hours than during the day; the maximum value is reached within two or three hours from midnight and the minimum value at sometime within 2 hours from noon—before noon at the coast stations after noon at the interior stations. The average amount (mean of 24 hours) is greater the nearer the line of sight is to the sea level, being some function of the altitude. The refraction changes but little, comparatively, between the hours of 10 a. m. and 5½ p. m. and the intervening time is best suited for observing zenith distances for altitudes, so far as refraction is concerned; but in other respects, as for telescopic visions. the hours about noon are unfavorable on account of faint, unsteady, and distorted images being then more prevalent. The diurnal range of the refraction also appears greatest at the lowest stations.

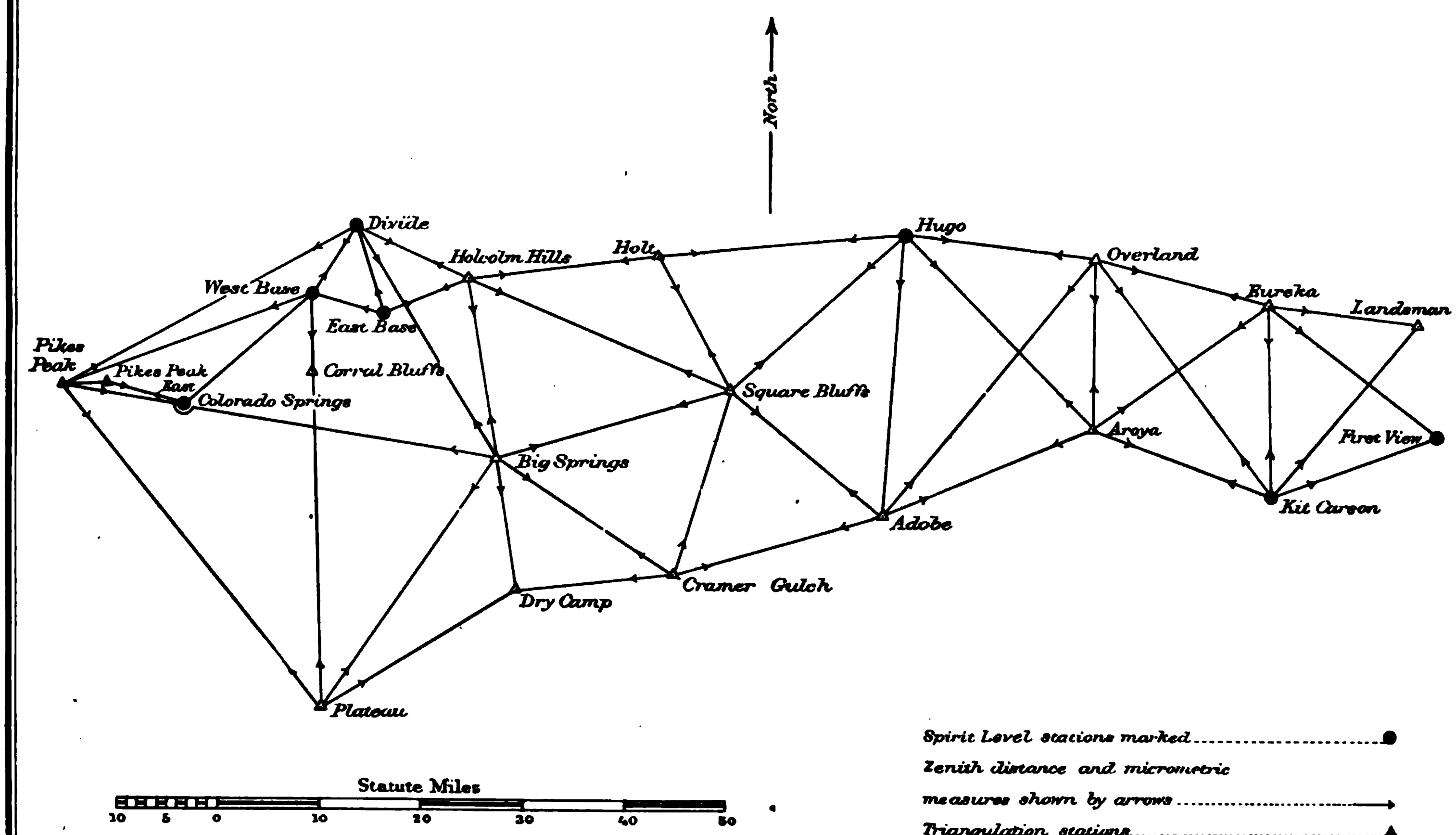
(B) DETERMINATION OF HEIGHTS OF PRINCIPAL TRIGONOMETRIC STATIONS IN EASTERN COLORADO FROM FIRST VIEW TO PIKES PEAK.

The measures of zenith distances and micrometric differences of height in eastern Colorado form a network covering a region 217 kilometres, or nearly 135 statute miles, in extent, as shown on the accompanying sketch. Seven of the vertical angle stations are connected directly with the line of spirit levels which terminates at present at the eastern flank of the Rocky Mountains. The heights above the St. Louis, Missouri, "Directrix" (bench mark K_3), of six of the stations, determined by spirit level, will be found in Appendixes Nos. 2 and 3, Report for 1898. The provisionally adopted height of the "Directrix" is 125·8 metres, or 412·7 feet. Hence we get the following resulting heights:

	Metres.
First View △	1 274·48+125·8 =1 400·28
Kit Carson △	1 219·65+125·8 =1 345·45
Hugo △	1 499·57+125·8 =1 625·37
Divide △	2 133·37+125·8 =2 259·17
El Paso Base, west end, top of monument	2 040·9 +125·8 =2 166·7
El Paso Base, west end, ground	2 166·7 — 1·05=2 165·65
Colorado Springs, nail marking level of vertical circle	1 696·35+125·8 =1 822·15

From the leveling of the El Paso Base by J. B. Weir of the party of Assistant O. H. Tittmann, in 1879, we have: El Paso Base, east end (top of monument) below west end (top of monument) 172·14 metres; hence height of El Paso Base, east end, top of monument, 2 166·7 — 172·14 = 1 994·56 metres and of El Paso Base, east end, ground, 1 994·56 — 1·06 = 1 993·50 metres.

Mr. Weir also leveled to Colorado Springs in 1879–80 and found: Colorado Springs, railroad track in front of Denver and Rio Grande Railroad passenger depot, below El Paso Base, west end, top of monument, 344·68 metres; hence height of railroad track at Colorado Springs = 2 166·7 — 344·68 = 1 822·02 metres. The height of approximately the same point derived directly from Assistant Winston's levels is 1 696·16 + 125·8 = 1 821·96 metres, showing a satisfactory agreement.



DETERMINATION OF HEIGHTS BETWEEN PIKES PEAK AND FIRST VIEW, COL.

1879 TO 1898

Finally, Pikes Peak △, from spirit-leveling by Assistant W. Eimbeck in 1895, is 4·898 metres above Pikes Peak East, where the vertical circle was mounted in order to permit the sighting of Colorado Springs.

I. ABSTRACTS OF RESULTING ZENITH DISTANCES.

These abstracts require but little explanation. The first column gives the number of days upon which observations were made (since the resulting ζ's were combined by days); the observed zenith distances are reduced to the ground at both stations; the columns headed P and T contain the rough values of the atmospheric pressure expressed in millimetres and of the atmospheric temperature expressed in degrees Centigrade; the log. of the distance s between the stations is given for metres. Notes appended state the extremes of time between which observations were obtained. No rejections were made of micrometric measures of differences of height.

Pikes Peak. July and August, 1895. Vertical Circles, Nos. 28 and 44. R. L. Faris, J. Nelson, and W. H. Clay, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (C.)	Log s.
		° ′ ″	″	″	° ′ ″	*mm.*	°	
11	Mount Ouray	90 28 52·8	− 0·6	+ 0·2	90 28 52·4	459	5·7	5·052 21
12	Mount Elbert	90 27 50·5	− 0·8	+ 0·3	90 27 50·0	460	6·2	5·097 79
10	Bison	90 44 05·0	+ 0·2	− 0·2	90 44 05·0	459	5·8	4·771 60
11	Divide	92 25 43·5	− 1·1	+ 1·2	92 25 43·6	460	6·7	4·721 59
9	Plateau	92 34 45·6	+18·7	− 14·9	92 34 49·4	460	5·8	4·816 21
13	Big Springs	92 14 53·5	+17·5	− 12·6	92 14 58·4	460	6·4	4·841 50

Observations between 11 hours 45 minutes a. m. and 1 hour 20 minutes p. m., and between 4 hours 30 minutes and 7 hours 5 minutes p. m.

Pikes Peak East. July and August, 1895. Vertical Circle, No. 44. R. L. Faris, observer; W. Eimbeck, chief of party.

		° ′ ″	″	″	° ′ ″	*mm.*	°	
2	Monte Rosa	93 37 38·4	+30·5	0·0	93 38 08·9	460	4·2	4·099 98
4	Colorado Springs	97 39 05·7	+ 8·8	0·0	97 39 14·5	460	5·8	4·268 83

Observations between 12 hours 35 minutes and 1 hour 10 minutes, and 5 hours 15 minutes and 6 hours 10 minutes p. m.

Colorado Springs. October, 1895. Vertical Circle, No. 44. R. L. Faris, observer; W. Eimbeck, chief of party.

		° ′ ″	″	″	° ′ ″	*mm.*	°	
4	Monte Rosa	82 58 55·8	+28·2	0·0	82 59 24·0	...	...	4·132 95
3	Pikes Peak East	82 28 47·8	+34·2	0·0	82 29 22·0	...	...	4·268 83

Observations between 4 hours 15 minutes and 5 hours 20 minutes p. m.

El Paso East Base. September and October, 1879. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and J. B. Weir, observers; O. H. Tittmann, chief of party.

		° ′ ″	″	″	° ′ ″	*mm.*	°	
4	Holcolm Hills	89 25 33·1	+ 54·7	0·0	89 26 27·8	...	...	4·132 55
3·5	Divide	88 54 26·2	+ 89·3	0·0	88 55 55·5	...	...	4·129 44
3·5	El Paso West Base	89 08 48·4	+104·5	0·0	89 10 32·9	...	...	4·052 66

Observations between 8 hours 15 minutes a. m. and 5 hours 15 minutes p. m.

El Paso West Base. October, 1879. Vertical Circle, No. 75. O. H. Tittmann, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (C.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
4	Divide	89 35 10·5	+104·2	+ 0·3	89 36 55·0	...	...	4·085 93
3	Pikes Peak	87 16 37·3	+ 28·8	+ 0·2	87 17 06·3	...	...	4·626 70
1	Corral Bluffs	90 29 27·3	+ 63·0	+ 0·5	90 30 30·8	...	...	4·082 01

Observations between 9 hours 5 minutes and 10 hours 15 minutes a. m., and between 3 hours and 4 hours p. m.

Divide. November, 1879. Vertical Circle, No. 75. O. H. Tittmann, observer and chief of party. July and August, 1895. Vertical Circle, No. 109. F. D. Granger and J. B. Boutelle, observers; F. D. Granger, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
4	El Paso West Base, 1879	90 27 41·1	+77·3	+ 0·4	90 28 58·8	...	....	4·085 93
4	Holcolm Hills, 1879	90 25 49·2	+41·1	− 0·3	90 26 30·0	...	....	4·269 17
11	Big Springs, 1895	90 39 16·1	− 1·6	0·0	90 39 14·5	578	22·9	4·623 06
12	Pikes Peak, 1895	87 59 24·9	+ 2·8	0·0	87 59 27·7	577	24·0	4·721 59
11	Bison, 1895	89 20 33·4	− 1·4	0·0	89 20 32·0	576	23·2	4·940 23
3	Monte Rosa, 1895	88 49 23·1	− 6·5	0·0	88 49 16·6	575	23·4	4·712 41

Observations in 1879 between 10 hours a. m. and 2 hours 10 minutes p. m.; in 1895, between 11 hours 35 minutes a. m. and 1 hour p. m., and between 4 hours 35 minutes and 6 hours 30 minutes p. m.

Plateau. July and August, 1894, September and October, 1895. Vertical Circle, No. 109. F. D. Granger, observer and chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
10	Pikes Peak	87 56 12·5	+ 9·2	0·0	87 56 21·7	616	30·4	4·816 21
13	Mount Ouray	89 33 20·8	− 0·5	0·0	89 33 20·3	614	30·0	5·163 93
10*	Big Springs	89 52 58·1	+ 0·7	0·0	89 52 58·8	615	27·5	4·679 47
7*	Dry Camp	90 02 22·2	+22·8	0·0	90 02 45·0	624	20·3	4·551 81
6	Corral Bluffs	89 45 14·9	− 5·9	0·0	89 45 09·0	622	19·2	4·725 24

Observations in 1894 between 11 hours 40 minutes a. m. and 1 hour 5 minutes p. m., and between 4 hours 45 minutes and 6 hours 55 minutes p. m.; in 1895 between 2 hours and 4 hours 40 minutes p. m.

* Double zenith distances: Of Big Springs, nine days; of Dry Camp, six days. One day added to each for two days' micrometric differences.

Big Springs. August and September, 1880. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers; O. H. Tittmann, chief of party. June and July, 1895. Vertical Circle, No. 109. F. D. Granger, J. B. Boutelle, observers; F. D. Granger, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (C.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
4	Holcolm Hills, 1880	89 36 47·3	+93·3	0·0	89 38 20·6	596	17·9	4·452 62
3	Square Bluffs, 1880	90 25 58·7	+46·6	0·0	90 26 45·3	...	....	4·585 22
3	Cramers Gulch, 1880	90 39 00·7	+15·0	0·0	90 39 15·7	...	....	4·518 59
12	Plateau, 1895	90 30 08·2	− 1·0	0·0	90 30 07·2	588	25·2	4·679 47
11	Pikes Peak, 1895	88 17 50·0	+ 6·8	0·0	88 17 56·8	588	27·2	4·841 50
11	Divide, 1895	89 41 05·4	− 1·7	0·0	89 41 03·7	587	25·0	4·623 06
1	Dry Camp, 1895	90 37 40·9	−16·7	0·0	90 37 24·2	586	25·0	4·328 92

Observations in 1880 between 10 hours 20 minutes and 11 hours 15 minutes a. m., and between 2 hours 5 minutes and 5 hours 35 minutes p. m., except one micrometric difference of Cramers Gulch at 6 hours 25 a. m.; in 1895 between noon and 1 hour 30 minutes p. m., and between 4 hours 40 minutes and 6 hours 45 minutes p. m.

Holcolm Hills. July and August, 1880. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and J. E. McGrath, observers; O. H. Tittmann, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (C.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
5	Divide	89 43 05·3	−48·0	0·0	89 42 17·3	584	23·6	4·269 17
4	Big Springs	90 36 12·5	−30·4	0·0	90 35 42·1	584	19·6	4·452 62
8	El Paso East Base	90 41 31·4	−78·5	0·0	90 40 12·9	584	19·2	4·132 55
6	Holt	90 39 01·0	−27·8	0·0	90 38 33·2	584	19·1	4·479 56
1	Square Bluffs	90 43 36·2	− 7·5	0·0	90 43 28·7	582	22·8	4·657 64

Observations between 7 hours 20 minutes and 11 hours 30 minutes a. m., mostly before 8 hours 15 minutes, and between 3 hours 10 minutes and 5 hours 40 minutes p. m.

Cramers Gulch. September, 1880. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers; O. H. Tittmann, chief of party. September, 1895. Vertical Circle, No. 109, and Theodolite, No. 118. F. D. Granger, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (C.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
2	Adobe, 1880	90 10 22·0	+53·2	0·0	90 11 15·2	621	31·1	4·533 56
2	Square Bluffs, 1880	89 54 25·5	+59·6	0·0	89 55 25·1	621	31·1	4·478 69
2	Big Springs, 1880	89 36 29·5	+38·7	0·0	89 37 08·2	621	31·1	
2	Big Springs, 1895	89 37 22·4	−18·2	0·0	89 37 04·2	625	30·8	
4	Big Springs, mean				89 37 06·2			4·518 59
6	Dry Camp, 1895	89 52 01·2	− 5·3	0·0	89 51 55·9	624	31·9	4·387 04

Observations in 1880 between 10 hours 25 minutes a. m. and 4 hours 35 minutes p. m.; in 1895 between 3 hours 35 minutes and 4 hours 55 minutes p. m.

Square Bluffs. September, 1880. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and J. E. McGrath, observers; O. H. Tittmann, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (C.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
4	Holt	89 43 13·7	+55·3	0·0	89 44 09·0	614	29·7	4·382 95
3	Holcolm Hills	89 38 00·6	+43·5	0·0	89 38 44·1	613	28·1	4·657 64
3	Big Springs	89 51 42·9	+33·1	0·0	89 52 16·0	613	28·1	4·585 22
3	Hugo	90 16 33·0	+49·1	0·0	90 17 22·1	615	24·6	4·567 11
3	Cramers Gulch	90 19 24·7	+16·4	0·0	90 19 41·1	615	24·6	4·478 69
2	Adobe	90 22 05·8	+59·0	0·0	90 23 04·8	616	21·9	4·487 16

Observations between 10 hours a. m. and 4 hours 25 minutes p. m.

Holt. October, 1880. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers; O. H. Tittmann, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
3	Square Bluffs	90 27 16·3	+76·3	0·0	90 28 32·6	605	22·2	4·382 95
2	Holcolm Hills	89 35 52·9	+65·8	0·0	89 36 58·7	602	28·9	4·479 56
3	Hugo	90 30 21·7	+45·8	0·0	90 31 07·5	599	25·2	4·600 35

Observations between 9 hours 30 minutes a. m. and 4 hours 35 minutes p. m.

Hugo. November, 1880. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers; O. H. Tittmann, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
4	Overland	90 08 23·2	+27·6	0·0	90 08 50·8	616	....	4·476 20
2	Holt	89 48 20·7	+33·4	0·0	89 48 54·1	621	....	4·600 35
2	Aroya	90 20 19·4	+18·8	0·0	90 20 38·2	621	....	4·620 92
2	Adobe	90 13 48·7	+40·8	0·0	90 14 29·5	621	....	4·646 49
2	Square Bluffs	90 00 20·0	+48·4	0·0	90 01 08·4	621	....	4·567 11

Observations between 9 hours 50 minutes a. m. and 3 hours 30 minutes p. m.

Adobe. July and August, 1881. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers; O. H. Tittmann, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
3	Aroya	90 16 09·5	+ 0·6	0·0	90 16 10·1	637	....	4·546 77
3	Overland	90 10 18·9	+ 0·4	0·0	90 10 19·3	638	....	4·716 81
3	Cramers Gulch	90 05 29·1	− 8·1	0·0	90 05 21·0	639	....	4·533 56
2	Square Bluffs	89 52 04·4	+33·3	0·0	89 52 37·7	639	....	4·487 16

Observations between 4 hours 15 minutes and 6 hours 5 minutes p. m.

Aroya. August and September, 1881. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers; O. H. Tittmann, chief of party.

		′ ″	″	″	° ′ ″	mm.	°	
3	Overland	9 50 53·7	+31·5	0·0	89 51 25·2	646	....	4·418 95
2	Kit Carson	90 23 57·3	+31·3	0·0	90 24 28·6	646	....	4·479 57
3	Hugo	89 58 57·0	+43·3	0·0	89 59 40·3	646	....	4·620 92
3	Adobe	90 00 35·8	+18·3	0·0	90 00 54·1	646	....	4·546 77
3	Eureka	90 13 04·5	+32·5	0·0	90 13 37·0	646	....	4·529 43

Observations between 8 hours 55 minutes a. m. and 4 hours 10 minutes p. m.

Overland. September, 1881. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers; O. H. Tittmann, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (C.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
3	Aroya	90 20 48·1	+32·7	0·0	90 21 20·8	...	....	4·418 95
3	Hugo	90 04 39·9	+61·4	0·0	90 05 41·3	...	....	4·476 20
3	Adobe	90 14 28·9	+13·0	0·0	90 14 41·9	...	....	4·716 81
3	Eureka	90 26 41·5	+41·1	0·0	90 27 22·6	...	....	4·440 09
3	Kit Carson	90 30 10·7	+20·2	0·0	90 30 30·9	...	....	4·664 01

Observations between 2 hours 5 minutes and 5 hours 35 minutes p. m.

Eureka. September and October, 1881. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers; O. H. Tittmann, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (C.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
5	Aroya	90 02 21·8	+24·4	0·0	90 02 46·2	647	....	4·529 43
4	Kit Carson	90 17 43·8	+29·4	0·0	90 18 13·2	647	....	4·485 81
4	Overland	89 45 34·5	+28·5	0·0	89 46 03·0	647	....	4·440 09
2	First View	90 11 51·3	+31·0	0·0	90 12 22·3	647	....	4·531 01
2	Landsman	90 08 34·1	+43·9	0·0	90 09 18·0	647	....	4·381 82

Observations between 2 hours 45 minutes and 5 hours p. m.

Kit Carson. October, 1881. Vertical Circle, No. 75, and Theodolite, No. 108. O. H. Tittmann, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (C.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
3	First View	90 00 00·8	+34·9	0·0	90 00 35·7	...	....	4·461 62
3	Landsman	90 01 30·2	+28·2	0·0	90 01 58·4	...	....	4·557 53
3	Eureka	89 56 10·8	+34·6	0·0	89 56 45·4	...	....	4·485 81
3	Aroya	89 50 08·7	+24·7	0·0	89 50 33·4	...	....	4·479 57
3	Overland	89 51 27·9	+16·1	0·0	89 51 44·0	...	....	4·664 01
3	First View house chimney	90 00 47·9	−12·9	0·0	90 00 35·0	...	....	4·484 57

Observations between 9 hours a. m. and 3 hours 5 minutes p. m.

2. DETERMINATION OF THE COEFFICIENT OF REFRACTION.

Let ζ_{I} and ζ_{II} be the observed reciprocal* zenith distances at the ends of a line of length s and radius of curvature ρ; then the mean coefficient of refraction m may be computed by the formula—

$$m = 0{\cdot}5 - \rho\frac{\sin 1''}{2s}(\zeta_{\text{I}} + \zeta_{\text{II}} - 180^\circ)$$

and the weight p for any value of m may be taken proportional to $\frac{n_{\text{I}}\, n_{\text{II}}}{n_{\text{I}} + n_{\text{II}}} \cdot s^2$,

where $n_{\text{I}}, n_{\text{II}}$ represent the number of days of observation at the two ends of the line. In case the difference of height $\triangle h$ be known from spirit leveling and one zenith distance ζ be observed, we may find m from the expression—

$$m = 0{\cdot}5 - \frac{\rho}{s^2}(\triangle h - s \cot \zeta)$$

and for its relative proportional weight we may take $\frac{ns^2}{4}$.

* Here non-simultaneous.

The resulting values of *m*, arranged according to length of sight (*s in kilometres*), and their respective weights are as follows:

Line.	*s.*	*m.*	*p.*
Pikes Peak to Big Springs	69·4	0·059 6	2·87
Pikes Peak to Plateau	65·5	·058 7	2·03
Pikes Peak to Divide	52·7	·056 2	1·59
Overland to Adobe	52·1	·055 0	0·41
Big Springs to Plateau	47·8	·052 4	1·25
Overland to Kit Carson	46·1	·053·2	0·32
Holcolm Hills to Square Bluffs	45·5	·046 3	0·15
Divide to Big Springs	42·0	·052 0	0·97
Hugo to Aroya	41·7	·049 4	0·21
Holt to Hugo	39·8	·033 0	0·19
Big Springs to Square Bluffs	38·5	·040 9	0·22
Square Bluffs to Hugo	36·9	·035 1	0·16
Adobe to Aroya	35·2	·050 0	0·19
Cramers Gulch to Adobe	34·2	·048 6	0·14
Aroya to Eureka	33·8	·050 7	0·21
Big Springs to Cramers Gulch	33·0	·039 8	0·19
Square Bluffs to Adobe	30·7	·025 5	0·09
Eureka to Kit Carson	30·6	·047 2	0·16
Holcolm Hills to Holt	30·2	·021 7	0·14
Aroya to Kit Carson	30·2	·037 4	0·11
Square Bluffs to Cramers Gulch	30·1	·035 8	0·11
Hugo to Overland	29·9	·048 9	0·15
Kit Carson to First View	28·9	·044 2	0·06
Holcolm Hills to Big Springs	28·4	·041 5	0·16
Overland to Eureka	27·5	·047 3	0·13
Overland to Aroya	26·2	·049 9	0·10
Holt to Square Bluffs	24·1	·013 4	0·10
* Divide to Holcolm Hills	18·6	·061 0	0·08
† Pikes Peak East to Colorado Springs	18·6	·071 1	0·06
Holcolm Hills to East Base	13·6	·043 0	0·05
‡ East Base to Divide	13·5	— ·009 8 (?)	0·02
Divide to West Base	12·2	·051 8	0·03
East Base to West Base	11·3	0·012 0	0·01

* Deep valley between the two stations.
† Line on steep incline and high above ground.
‡ Not used.

Forming three groups of 10 values each, we find the means—

	s_0	m_0
	50·3 km.	0·056 0
	33·3	0·040 5
	23·2	0·040 9
General mean		0·053 0

The tabular values of m show an apparent dependence upon the length of lines s, viz: the shorter s, the smaller m. This fact may be explained by the circumstance of the line of sight being nearer the heated ground the shorter the distance. The comparatively warm stratum of air is quite close to the ground, particularly during insolation. The two apparent exceptions marked * and † prove the rule. The ground is barren and treeless over the entire region and the climate is very dry, especially during the summer. The instrument was only elevated sufficiently to overcome the earth's curvature and permit the visibility of the distant object.

3. DETERMINATION OF DIFFERENCES OF HEIGHT AND THEIR ADJUSTMENT.

For computing the difference of height $h_{II} - h_I$ of two stations where reciprocal zenith distances ζ_{II} and ζ_I were observed, supposed simultaneously, the formula—

$$\triangle h = h_{II} - h_I = s \tan \tfrac{1}{2} (\zeta_{II} - \zeta_I)\left[1 + \frac{h_I + h_{II}}{2\rho} + \frac{s^2}{12\rho^2} + \ . \ . \ . \ \right]$$

was used, and the weight p was taken equal to $\frac{(n_I n_{II})\, 10^{10}}{(n_I + n_{II})\, s^2}$; when but one zenith distance was observed, and consequently a value for m had to be assumed, we have—

$$\triangle h = s \cot \zeta + \frac{1 - 2m}{2\rho} s^2 + \frac{1 - m}{\rho} s^2 \cot^2 \zeta + \ . \ . \ . \ .$$

with the assumed relative weight $= \frac{(n)\, 10^{10}}{4s^2}$ where $n =$ number of days of observation; in the latter case, for the line West Base to Pikes Peak m was taken equal to 0·061 4, which is the mean resulting value for the other four lines to Pikes Peak. The differences of height for the few remaining lines with but one zenith distance were computed with $m = 0{\cdot}047\ 4$.

A table of values of log. ρ is given in Appendix No. 18, Report for 1876, pp. 384–387; below we append a table specially adapted for the computations in connection with the transcontinental arc. It is based upon Clarke's spheroid of 1866. We have the expression—

$$\text{Radius of curvature, } \rho = \frac{a\,(1 - e^2)}{(1 - e^2 + e^2 \cos^2 \alpha \cos^2 \phi)(1 - e^2 \sin^2 \varphi)^{\frac{1}{2}}}$$

Azimuth \ Latitude	*Values of log. ρ.* 38°	38½°	39°	39½°	40°	40½°	Difference for 10′ of latitude, in units of sixth place of decimals.
(Meridian) 0°	6·803 422	6·803 460	6·803 497	6·803 535	6·803 573	6·803 611	13
5	436	473	511	548	586	624	13
10	478	515	552	589	626	663	12
15	546	582	618	654	690	726	12
20	637	671	706	741	776	811	12
25	749	782	815	848	3 882	3 916	11
30	3 880	3 911	3 943	3 974	4 006	4 038	11
35	4 025	4 054	4 083	4 112	142	172	10
40	179	206	234	261	289	316	9
45	338	363	388	414	439	464	8
50	498	521	544	567	590	613	8
55	652	673	694	715	736	757	7
60	797	816	835	854	873	4 892	6
65	4 928	4 945	4 962	4 979	4 996	5 013	6
70	5 041	5 056	5 072	5 088	5 104	120	5
75	133	147	161	176	190	205	5
80	201	214	227	241	254	268	4
85	242	255	268	281	294	307	4
(Prime vert.) 90	6·805 256	6·805 268	6·805 281	6·805 294	6·805 307	6·805 320	4

Resulting differences of heights from reciprocal nonsimultaneous zenith distances.

Stations.	Δh. (m.)	p.	Stations.	Δh. (m.)	p.
Pikes Peak and Divide	2 041·954	20·70	Square Bluffs and Holt	155·988	29·38
Pikes Peak and Big Springs	2 395·441	12·36	Square Bluffs and Hugo	87·137	8·81
Pikes Peak and Plateau	2 655·317	11·04	Square Bluffs and Adobe	136·017	10·62
Pikes Peak East and Colorado Springs (V. C.)	2 473·197	49·66	Holt and Hugo	244·749	7·55
Divide and Big Springs	355·372	31·26	Hugo and Aroya	127·417	6·87
Divide and Holcolm Hills	119·553	64·42	Hugo and Overland	13·754	19·14
Holcolm Hills and East Base	145·603	144·90	Adobe and Cramers Gulch	29·339	10·28
Holcolm Hills and Big Springs	236·623	24·89	Adobe and Aroya	78·221	12·08
Holcolm Hills and Holt	270·283	16·48	Overland and Adobe	33·170	5·52
Holcolm Hills and Square Bluffs	428·236	3·63	Overland and Aroya	114·240	21·78
Big Springs and Plateau	258·304	23·88	Overland and Eureka	165·625	22·59
Big Springs and Square Bluffs	193·071	10·14	Overland and Kit Carson	260·281	7·05
Big Springs and Cramers Gulch	298·484	15·74	Aroya and Eureka	53·398	16·37
Square Bluffs and Cramers Gulch	106·295	13·24	Aroya and Kit Carson	148·877	13·18
			Eureka and Kit Carson	95·566	18·28

Resulting differences of height from single zenith distances and assumed m.

Stations.	Δh.	p.
	m.	
West Base and Corral Bluffs	96·828	17·14
Plateau and Corral Bluffs	430·244	5·31
Plateau and Dry Camp	61·561	13·77
Big Springs and Dry Camp	199·676	5·50
Cramers Gulch and Dry Camp	99·354	25·23
Hugo and Adobe	47·081	2·55
Eureka and Landsman	24·041	8·61
Kit Carson and Landsman	71·860	5·75
Eureka and First View	40·362	4·34
West Base and Pikes Peak	2 135·893	4·19

Fixed heights determined by spirit levels.

	Metres.	*Feet.*		*Metres.*	*Feet.*
El Paso West Base	2 165·65	7 105. 1	Hugo	1 625·37	5 332·6
El Paso East Base	1 993·50	6 540·3	Kit Carson	1 345·45	4 414·2
Colorado Springs (V. C.)	1 822·15	5 978·2	First View	1 400·28	4 594·1
Divide	2 259·17	7 412·0			

Pikes Peak above Pikes Peak East 4·898 metres.

Assumed heights.

	Metres.		*Metres.*
Pikes Peak	4 301 $+x_1$	Square Bluffs	1 711 $+x_8$
Holcolm Hills	2 139 $+x_2$	Holt	1 868 $+x_9$
Big Springs	1 904 $+x_3$	Adobe	1 576 $+x_{10}$
Plateau	1 645 $+x_4$	Aroya	1 496 $+x_{11}$
Corral Bluffs	2 071 $+x_5$	Overland	1 610 $+x_{12}$
Dry Camp	1 706 $+x_6$	Eureka	1 442 $+x_{13}$
Cramers Gulch	1 606 $+x_7$	Landsman	1 417 $+x_{14}$

To the observation equations as given below the respective weights are attached, and a column is added showing the discrepancy between the direct measure and the adjusted measure.

Observation equation.	p.	Dis-crepancy.	Observation equation.	p.	Dis-crepancy.
		m.			*m.*
$0=+0{\cdot}755+x_1$	49·66	−0·05	$0=+1{\cdot}012-x_8+x_9$	29·38	+0·57
$-0{\cdot}124+x_1$	20·70	−0·93	$-2{\cdot}119+x_9$	7·55	−1·91
$-0{\cdot}543+x_1$	4·19	−1·35	$-1{\cdot}507+x_8$	8·81	−0·86
$-0{\cdot}103+x_2$	144·90	−0·48	$-2{\cdot}289+x_{10}$	2·55	−2·90
$-0{\cdot}617+x_2$	64·42	−0·99	$+1{\cdot}017-x_8+x_{10}$	10·62	−0·24
$+0{\cdot}202+x_3$	31·26	−0·47	$-0{\cdot}661-x_7+x_{10}$	10·28	−0·40
$+1{\cdot}623-x_2+x_3$	24·89	+1·32	$-1{\cdot}953+x_{11}$	6·87	−2·27
$-1{\cdot}559-x_1+x_3$	12·36	−1·43	$+1{\cdot}673+x_{11}$	13·18	+1·36
$-0{\cdot}683-x_1+x_4$	11·04	−0·87	$-1{\cdot}779-x_{10}+x_{11}$	12·08	−1·48
$-0{\cdot}696-x_3+x_4$	23·88	−1·01	$-1{\cdot}616+x_{12}$	19·14	−2·37
$+2{\cdot}178+x_5$	17·14	+1·29	$+4{\cdot}269+x_{12}$	7·05	+3·52
$-4{\cdot}244-x_4+x_5$	5·31	−4·15	$+0{\cdot}830-x_{10}+x_{12}$	5·52	+0·69
$+1{\cdot}676-x_3+x_6$	5·50	+1·07	$-0{\cdot}240-x_{11}+x_{12}$	21·78	−0·68
$-0{\cdot}561-x_4+x_6$	13·77	−0·85	$+0{\cdot}984+x_{13}$	18·28	+1·22
$+0{\cdot}484-x_3+x_7$	15·74	+0·29	$+1{\cdot}358+x_{13}$	4·34	+1·59
$-0{\cdot}646-x_6+x_7$	25·23	−0·23	$-0{\cdot}602-x_{11}+x_{13}$	16·37	−0·05
$+0{\cdot}236-x_2+x_8$	3·63	+1·26	$-2{\cdot}375-x_{12}+x_{13}$	22·59	−1·39
$+0{\cdot}071-x_3+x_8$	10·14	+1·40	$-0{\cdot}310+x_{14}$	5·75	+0·53
$-1{\cdot}295-x_7+x_8$	13·24	+0·22	$-0{\cdot}959-x_{13}+x_{14}$	8·61	−0·35
$-0{\cdot}717-x_2+x_6$	16·48	−0·14			

Forming the normal equations and solving them, we get the following:

Resulting values of x, and final heights.

Station (ground).	x.	Height—In metres.	Height—In feet.
	m.		
Pikes Peak	−0·804	4 300·196	14 108·2
Holcolm Hills	−0·374	2 138·626	7 016·5
Big Springs	−0·674	1 903·326	6 244·8
Plateau	−0·989	1 644·011	5 393·7
Corral Bluffs	−0·893	2 070·107	6 791·7
Dry Camp	−1·279	1 704·721	5 592·9
Cramers Gulch	−0·865	1 605·135	5 266·2
Square Bluffs	+0·650	1 711·650	5 615·6
Holt	+0·206	1 868·206	6 129·3
Adobe	−0·609	1 575·391	5 168·6
Aroya	−0·314	1 495·686	4 907·1
Overland	−0·750	1 609·250	5 279·7
Eureka	+0·236	1 442·236	4 731·7
Landsman	+0·841	1 417·841	4 651·7

That the corrections needed to harmonize the results by spirit levels and vertical angles should be of the magnitude shown above is attributed largely to the difficulty of securing a sufficient number of vertical angle measures during the time when "seeing" was practicable. Observations were made at all hours of the day, beginning sometimes before 6 a. m. and reaching to 5¾ p. m. While at some stations fairly numerous observations were secured, at others they were barely sufficient. As a rule (with some exceptions) the early observations—say those made before 9 or 10 a. m.—and some late ones in the afternoon could not be included, the refraction being then much above its ordinary minimum daily amount.

The field measures do not warrant us to give the resulting heights closer than one-tenth of a metre, or in English measures, say about 1 foot, though, as usual, the adjustment is carried farther for security.

The height of Pikes Peak being of special interest on account of the meteorological observations made at the summit, we may compare the results from the angular measures in connection with each of the five stations lying round the Eastern Base of the mountain. The heights of three of these stations were fixed by spirit leveling; those of the other two are taken as adjusted. The differences of height *as measured* are used.

Height of Pikes Peak* △ (bolt) from—

	m.	m.		m.	p.
Divide	2 259·17+	2 041·95	=	4 301·12	20·7
El Paso West Base	2 165·65+	2 135·89	=	4 301·54	4·2
Colorado Springs	1 822·15+	2 473·20 +4·90	=	4 300·25	49·7
Big Springs	1 903·33+	2 395·44	=	4 298·77	12·4
Plateau	1 644·01+	2 655·32	=	4 299·33	11·0
Weighted mean				4 300·20±	0·27
				or 14 108·2 feet.	

Taking into consideration the probable error of the adjusted height system, that of Pikes Peak may be estimated as $\sqrt{(\cdot 25)^2+(\cdot 25)^2+(\cdot 27)^2} = \pm 0 \cdot 45$ metre.

C. DETERMINATION OF HEIGHTS OF TRIGONOMETRIC STATIONS IN THE VICINITY OF THE COAST RANGE OF CALIFORNIA FROM POINT ARENA TO MOUNT DIABLO.

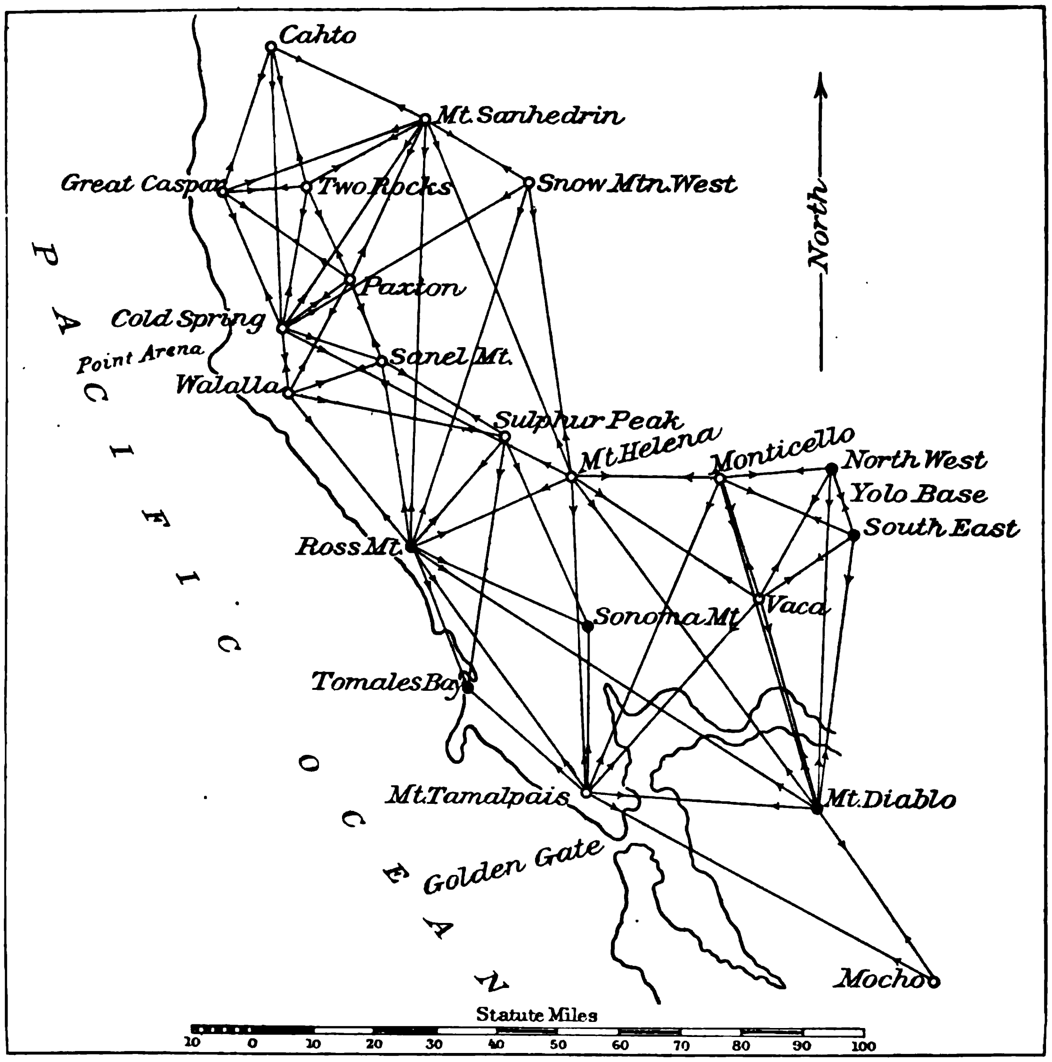
1. INTRODUCTION.

Some of the heights in this region have already been treated in Appendix No. 10, Coast and Geodetic Survey Report for 1884, in connection with the adjustment of the triangulation about the Yolo Base, but the present discussion embraces a larger number and a more complex system of measures, as shown on the accompanying diagram.

*An additional value for the height of Pikes Peak may be obtained from information furnished by Mr. H. I. Reid, civil engineer, in a letter to Assistant I. Winston, dated Colorado Springs, Colorado, June 27, 1898. From the levels of the Manitou and Pikes Peak Railway, checked by himself to about the 12 000-foot level, he finds the difference of height between the top and center of marble block on east side of signal station on Pikes Peak and the bench mark at the Denver and Rio Grande passenger depot at Colorado Springs, called by Assistant Winston, "City bench mark," to be 14 112·83 − 6 002·73 = 8 110·10 feet = 2 471·96 metres. From Winston's spirit level, elevation of "City bench mark," 1 696·57 + 125·8 = 1 822·37 metres. Hence, elevation of top of marble block 4 294·33 metres. From levels by Mr. Winston, July 14, 1898, we have elevation of Pikes Peak △ (bolt) above marble block 16·48 feet = 5·02 metres; hence height of Pikes Peak △ (bolt) 4 299·35 metres.

As stated in the Report for 1884, the heights were at that time based upon tidal observations and lines of spirit levels to four stations. To these, two have now been added—viz, Sonoma Mountain and Tomales Bay, which are sufficiently well connected with tide water for the purpose, though otherwise weak for want of vertical measures to surrounding stations. We have the following particulars respecting these fundamental stations and their tidal connections:

No. 17.



Sonoma Mountain.—A line of spirit levels connects with tide water at Petaluma Bridge. It was run by D. Kerr and C. B. Ellis, under the direction of G. A. Fairfield, in June, July, and August, 1855.

Tomales Bay.—A line of spirit levels, run by C. B. Ellis under the direction of G. A. Fairfield, in March, 1856, connects with Flattened Rock, Tomales Bay, where tidal observations were made.

Ross Mountain.—A line of spirit levels, run by G. Davidson in August, 1860, connects the tidal bench mark with the triangulation station at Bodega Head. The line thence to Ross Mountain was leveled in January, February, and March, 1872, by S. R. Throckmorton and H. J. Willey. For particulars see Appendix No. 16, Report for 1876.

Mount Diablo.—This station was connected by spirit levels with Martinez East in May, 1880, by B. A. Colonna. In the same month B. A. Colonna and J. J. Gilbert connected Martinez East with the tidal bench mark at Benicia Arsenal, on the other side of Karquines Strait, by means of reciprocal simultaneous zenith distances. See Appendix No. 12, Report for 1883.

The ends of the Yolo Base.—The base line was leveled twice by B. A. Colonna in August, 1880, and he also connected the northwest end with the California Pacific railroad station at Woodland, of which the elevation was determined by the railroad engineers. See Appendix No. 11, Report for 1883.

Resulting heights of fundamental stations above the average level of the Pacific Ocean:

	m.	m.	
Sonoma Mountain	698·56	±0·25	
Tomales Bay	205·13	0·25	
Ross Mountain	672·23	0·15	
Mount Diablo	1 173·10	0·20	The probable errors are estimated.
Yolo Base, southeast	21·66	0·35	
Yolo Base, northwest	46·66	0·35	

2. ABSTRACTS OF RESULTING ZENITH DISTANCES AT STATIONS NEAR THE PACIFIC COAST BETWEEN POINT ARENA AND MOUNT DIABLO.

The contents of these abstracts need little explanation. The observed zenith distances are corrected when necessary for eccentric mounting of the instrument or heliotrope and for reduction to ground or to station mark at both the station occupied and the station sighted. The columns headed P and T give the approximate atmospheric pressure (expressed in millimetres and column reduced to 0° C.) and the temperature of the air (in degrees of the centigrade scale). The values of log. s are taken from the latest adjustment of the triangulation.

Southeast Yolo Base. August, 1880. Vertical Circle, No. 80. E. F. Dickins, observer; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ.	P.	T (Cent.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
8	Northwest Yolo Base	89 59 56·7	+14·6	−0·7	90 00 10·6	750	32·2	4·242 70
7	Mount Diablo	89 21 53·7	− 4·6	+1·1	89 21 50·2	750	33·2	4·859 91
6	Marysville Butte	89 49 20·4	− 4·0	−0·8	89 49 15·6	751	32·4	4·876 60
8	Vaca	88 46 02·0	−11·9	−0·1	88 45 50·0	751	33·4	4·477 55
8	Monticello	88 44 35·0	−10·4	−3·0	88 44 21·6	750	32·7	4·570 08

Observations mostly between 2 hours 30 minutes and 5 hours 30 minutes p. m.

Northwest Yolo Base. August and September, 1880. Vertical Circle, No. 80. J. J. Gilbert, observer; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ.	P.	T (Cent.)	Log. s.
		° ′ ″	″	″	° ′ ″	mm.	°	
10	Vaca	89 08 51·3	−2·7	+0·1	89 08 48·7	753	33·6	4·590 91
8	Pine Hill	89 51 11·8	−0·8	+0·1	89 51 11·1	754	32·7	4·878 89
11	Marysville Butte	89 38 29·2	−0·8	−0·2	89 38 28·2	753	33·6	4·767 95
10	Southeast Yolo Base	90 07 40·2	+104·6	0·0	90 09 24·8	753	33·7	4·242 70
9	Monticello	88 21 26·8	−4·6	−0·8	88 21 21·4	753	33·5	4·461 00
6	Mount Diablo	89 36 44·0	−0·9	+0·2	89 36 43·3	754	31·3	4·947 45

Observations mostly between 2 hours and 5 hours 30 minutes p. m.

Monticello, October, 1880. Vertical Circle, No. 80. E. F. Dickins, observer; George Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	Log s.
8	Northwest Yolo Base	91 51 38·9	+19·6	−2·3	91 51 56·2	682	18·6	4·461 00
8	Southeast Yolo Base	91 31 56·0	+50·8	−2·0	91 32 44·8	682	18·9	4·570 08
8	Mount Helena	89 34 05·1	− 0·1	−0·9	89 34 04·1	682	19·2	4·586 33
7	Mount Diablo	90 11 47·9	− 0·2	+0·4	90 11 48·1	683	18·8	4·954 72
6	Mount Tamalpais	90 26 19·3	− 1·0	+0·1	90 26 18·4	682	18·2	4·951 71
8	Marysville Butte	90 30 11·4	+ 0·2	0·0	90 30 11·6	682	18·3	4·833 70
6	Vaca	90 28 45·0	− 1·3	−0·4	90 28 43·3	683	19·9	4·522 07
7	Pine Hill	90 33 37·4	0·0	+0·1	90 33 37·5	682	18·1	5·019 41

Observations mostly between 2 hours and 5 hours 30 minutes p. m.

Vaca. November, 1880. Vertical Circle, No. 80. E. F. Dickins, observer; George Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	Log s.
10	Southeast Yolo Base	91 26 50·2	+63·2	+1·1	91 27 54·5	701	16·6	4·477 55
10	Northwest Yolo Base	91 08 57·4	+14·9	+0·9	91 09 13·2	701	15·6	4·590 91
9	Monticello	89 46 57·0	0·0	−0·9	89 46 56·1	701	17·2	4·522 07
10	Mount Diablo	89 46 02·7	− 0·1	+0·7	89 46 03·3	701	15·7	4·754 58
8	Marysville Butte	90 25 03·6	+ 0·3	−0·2	90 25 03·7	701	14·4	4·977 57
7	Mount Tamalpais	90 12 27·3	− 1·1	+0·2	90 12 26·4	701	14·4	4·827 98
5	Pine Hill	90 26 30·5	+ 0·1	−0·1	90 26 30·5	700	16·0	5·011 71
10	Mount Helena	89 38 12·7	+ 0·1	−0·6	89 38 12·2	701	16·3	4·762 76

Observations mostly between 1 hour and 4 hours 30 minutes p. m.

*Mount Tamalpais.** February, March, and April, 1859. Vertical Circle, No. 80. George Davidson, observer and chief of party. September and October, 1882. Vertical Circle, No. 111. E. F. Dickins and J. F. Pratt, observers; George Davidson, chief of party.

Number of days.	Object observed.		Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (Cent.)	Log. *s.*
			° ′ ″	″	″	° ′ ″	*mm.*	°	
6	Tomales,	1859	90 56 55·7	− 0·8	0·0	90 56 54·9	698	7·5	4·623 33
4	Sonoma,	1859	90 16 50·2	− 0·6	0·0	90 16 49·6	698	5·1	4·646 88
3	Mount Diablo,	1859	89 51 33·5	+13·1	0·0	89 51 46·6	699	7·8	
3	Mount Diablo,	1859	89 51 33·3	− 5·2	0·0	89 51 28·1	700	5·1	
13	Mount Diablo,	1882	89 51 33·2	+ 0·3	0·0	89 51 33·5	694	21·2	
19	Mount Diablo, mean					89 51 34·7			4·779 64
9	Mount Helena,	1882	89 56 54·0	+ 1·2	+0·4	89 56 55·6	693	17·1	4·918 06
7	Monticello,	1882	90 15 20·0	+ 0·3	+0·3	90 15 20·6	694	18·4	4·951 71
8	Vaca,	1882	90 18 32·4	+ 0·9	+0·2	90 18 33·5	694	19·9	4·827 98
11	Sierra Morena,	1882	90 17 01·9	+ 2·5	−0·2	90 17 04·2	694	21·9	4·795 34
7	Mocho,	1882	90 08 43·6	+ 0·4	−0·1	90 08 43·9	694	19·5	5·018 31
7	Ross Mountain,	1882	90 23 19·4	+ 1·5	+0·1	90 23 21·0	693	18·7	4·898 47

Observations in 1859 between 7 hours 30 minutes and 10 hours 20 minutes a. m., and between 3 hours 20 minutes and 5 hours p. m.; in 1882 mostly between noon and 4 hours 30 minutes p. m.

Mount Diablo. August and September, 1876. Vertical Circle, No. 37. W. Eimbeck, observer; George Davidson, chief of party. November and December, 1884. Vertical Circle, No. 80. F. Morse, observer; George Davidson, chief of party.

			° ′ ″	″	″	° ′ ″	*mm.*	°	Log *s.*
8	Mount Helena,	1876	90 19 49·6	+ 4·9	+0·6	90 19 55·1	662	19·1	5·032 33
7	Mount Tamalpais,	1876	90 35 40·3	+ 9·0	−0·1	90 35 49·2	662	17·9	4·779 64
8	Monticello,	1876	90 29 43·5	+ 6·0	+0·2	90 29 49·7	662	18·4	4·954 72
8	Vaca,	1876	90 39 50·1	+ 9·5	−0·1	90 39 59·5	662	19·0	4·754 58
8	Round Top,	1876	90 06 57·4	+ 2·9	−1·1	90 06 59·2	662	17·3	5·275 46
6	Marysville Butte,	1876	90 45 37·8	+ 3·6	0·0	90 45 41·4	662	16·1	5·167 94
6	Mount Lolo,	1876	90 25 07·6	+ 2·3	−0·6	90 25 09·3	661	16·2	5·339 85
3	Pine Hill,	1876	90 43 25·1	+ 4·4	−0·3	90 43 29·2	662	15·7	5·090 55
6	Mocho,	1876	90 07 54·3	+ 4·7	−0·7	90 07 58·3	661	17·7	
12	Mocho,	1884	90 07 26·4	+10·7	−0·7	90 07 36·4	654	11·0	
18	Mocho, mean					90 07 43·7			4·739 49
12	Ross Mountain,	1884	90 41 30·1	+ 5·1	+0·6	90 41 35·8	653	12·3	5·101 37
10	Southeast Yolo Base,	1884	91 10 26·8	+12·3	+0·2	91 10 39·3	654	10·0	4·859 91
6	Northwest Yolo Base,	1884	91 03 26·6	+10·1	0·0	91 03 36·7	654	7·1	4·947 45

Observations in 1876 mostly between 5 hours 15 minutes and 8 hours a. m., and between 3 hours 20 minutes and 7 hours p. m.; in 1884 between 10 hours a. m. and 1 hour p. m.

* Formerly Table Mountain; name changed to Mount Tamalpais in 1884.

Mocho. September and October, 1887. Vertical Circle, No. 57. P. A. Welker, observer; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ.	P.	T (Cent.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
12	Loma Prieta	90 17 32·3	+ 5·1	0·0	90 17 37·4	657	24·4	4·681 43
10	Mount Diablo	90 17 04·3	+ 1·0	+0·1	90 17 05·4	657	24·4	4·739 49
13	Santa Ana	90 23 19·9	+ 3·3	0·0	90 23 23·2	657	24·3	4·843 05
11	Sierra Morena	90 41 17·9	+ 1·9	0·0	90 41 19·8	657	25·0	4·826 15
6	Mount Tamalpais	90 38 21·1	+ 0·9	+0·1	90 38 22·1	656	21·5	5·018 32
5	Round Top	90 08 55·2	+ 0·1	−0·1	90 08 55·2	654	26·0	5·277 86
9	Mount Conness	90 03 37·4	− 0·5	−0·2	90 03 36·7	656	21·7	5·310 41

Observations between 11 hours 30 minutes a. m. and 1 hour 20 minutes p. m.

Mount Helena. October and November, 1876. Vertical Circle, No. 37. W. Eimbeck, observer; George Davidson, chief of party. August, 1891. Vertical Circle, No. 80. F. Westdahl, observer; E. F. Dickins, chief of party.

Number of days.	Object observed.		Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ.	P.	T (Cent.)	Log s.
			° ′ ″	″	″	° ′ ″	mm.	°	Log s.
8	Mount Diablo,	1876	90 29 03·5	+ 1·8	+0·5	90 29 05·8	652	10·7	
6	Mount Diablo,	1891	90 29 36·5	+ 3·1	+0·5	90 29 40·1	648	30·6	
14	Mount Diablo, mean					90 29 20·5			5·032 33
4	Mount Lola,	1876	90 24 27·7	+ 0·9	+0·3	90 24 28·9	654	11·8	5·330 15
10	Vaca,	1876	90 48 17·3	+ 3·7	−0·6	90 48 20·4	652	10·6	4·762 76
8	Marysville Butte,	1876	90 46 14·6	+ 2·2	0·0	90 46 16·8	652	9·1	4·965 06
7	Snow Mountain East,	1876	89 42 28·3	+ 2·6	−1·2	89 42 29·7	652	10·7	4·902 78
7	Snow Mountain West,	1891	89 43 03·4	+ 2·6	−1·2	89 43 04·8	648	30·7	4·899 27
8	Mount Tamalpais,	1876	90 40 46·8	+ 2·6	+0·1	90 40 49·5	653	9·2	
5	Mount Tamalpais,	1891	90 40 57·4	+ 3·6	+0·1	90 41 01·1	648	30·2	
13	Mount Tamalpais, mean					90 40 54·0			4·918 06
9	Round Top,	1876	90 23 56·4	+ 0·9	+0·6	90 23 57·9	652	8·3	5·360 02
7	Monticello,	1876	90 43 32·1	− 1·7	−0·8	90 43 29·6	652	7·8	4·586 33
6	Pine Hill,	1876	90 48 20·8	+ 1·5	+0·3	90 48 22·6	654	10·8	5·155 48
9	Ross Mountain,	1876	90 58 50·7	− 1·4	+0·5	90 58 49·8	653	9·3	
10	Ross Mountain,	1891	90 58 59·9	+ 6·6	+0·6	90 59 07·1	648	29·2	
19	Ross Mountain, mean					90 58 58·9			4·664 02
8	Cold Spring,	1891	90 39 24·4	+ 3·3	−0·2	90 39 27·5	649	29·0	4·937 51
7	Mount Sanhedrin,	1891	90 05 06·0	+ 2·9	−0·9	90 05 08·0	648	28·4	5·009 24

Observations in 1876 mostly between 6 hours 40 minutes and 9 a.m., and between 3 hours 30 minutes and 5 hours p.m.; in 1891, between 11 hours 45 minutes a.m. and 1 hour 5 minutes p.m.

Ross Mountain. December, 1859, and January, 1860. Vertical Circle, No. 28. G. Davidson, A. T. Mosman, E. H. Fauntleroy and "E. F.," observers; George Davidson, chief of party. July, 1891. Vertical Circle, No. 80. E. F. Dickins and F. Westdahl, observers; E. F. Dickins, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ.	P.	T (Cent.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
6	Sulphur Peak, 1859	89 33 20.8	− 8.3	0.0	89 33 12.5	...	10.4	4.573 23
5	Sanel, 1859	89 47 13.0	− 6.2	0.0	89 47 06.8	...	10.0	4.698 23
5	Tomales, 1859, 1860	90 49 25.5	− 0.7	0.0	90 49 24.8	...	9.4	4.590 79
4	Sonoma, 1859, 1860	90 09 24.8	− 0.4	0.0	90 09 24.4	...	10.6	4.713 52
4	Walalla, 1859, 1860	90 11 08.8	− 1.0	0.0	90 11 07.8	748	5.2	4.707 64
10	Mount Sanhedrin, 1891	89 49 14.0	+ 0.1	0.0	89 49 14.1	704	29.3	5.050 02
11	Snow Mountain West, 1891	89 34 04.6	+ 0.1	+0.1	89 34 04.8	704	29.4	5.007 34
12	Mount Helena, 1891	89 22 11.4	0.0	+0.7	89 22 12.1	704	27.8	4.664 02
8	Mount Diablo, 1891	90 14 50.4	+ 0.4	+0.2	90 14 51.0	704	28.6	5.101 37
9	Mount Tamalpais, 1891	90 12 18.5	+ 0.2	+0.1	90 12 18.8	704	29.7	4.898 47

Observations in 1859 and 1860 mostly between 9 hours a.m. and noon, and between 2 hours and 3 hours 45 minutes p.m.; in 1891, between 11 hours 50 minutes a.m. and 1 hour 10 minutes p.m.

Snow Mountain West. May and June, 1892. Vertical Circle, No. 111. F. Westdahl, observer; E. F. Dickins, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	Log s.
9	Mount Helena	90 54 16.4	− 0.2	0.0	90 54 16.2	586	10.4	4.899 27
7	Cold Spring	91 16 30.8	+ 0.2	−0.2	91 16 30.8	586	12.3	4.885 84
6	Ross Mountain	91 13 39.1	0.0	0.0	91 13 39.1	587	13.3	5.007 34
8	Mount Sanhedrin	90 35 09.8	− 7.9	−0.3	90 35 01.6	586	10.8	4.517 09
7	Snow Mountain East	89 41 20.2	+65.4	−6.5	89 42 19.1	585	9.0	2.965 59

Observations between 11 hours 45 minutes a.m. and 1 hour 10 minutes p.m.

Cold Spring. October, 1878. Vertical Circle, No. 37. B. A. Colonna, E. F. Dickins, observers; B. A. Colonna, chief of party. October and November, 1891. Vertical Circle, No. 80. E. F. Dickins and F. Westdahl, observers; E. F. Dickins, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	Log s.
5	Great Caspar, 1878	90 50 05.3	+219.6	0.0	90 53 44.9	685	....	4.594 46
7	Two Rock, 1878	90 08 15.5	+ 3.1	0.0	90 08 18.6	685	....	4.582 89
7	Walalla, 1878	90 33 09.5	+55.7	0.0	90 34 05.2	684	....	4.267 79
6	Snow Mountain West, 1891	89 18 50.1	+ 4.6	+0.5	89 18 55.2	691	14.7	4.885 84
6	Mount Helena, 1891	90 00 16.2	+ 4.0	+0.1	90 00 20.3	692	14.2	4.937 51
7	Mount Sanhedrin, 1878	89 20 33.0	+ 5.5	0.0	89 20 38.5	685	....	
5	Mount Sanhedrin, 1891	89 20 17.6	+ 4.0	+0.2	89 20 21.8	692	13.7	
12	Mount Sanhedrin, mean				89 20 31.5			4.819 82
7	Paxton, 1878	89 32 51.7	+46.1	0.0	89 33 37.8	685	....	
7	Paxton, 1891	89 32 42.2	+36.3	+0.7	89 33 19.2	691	14.8	
14	Paxton, mean				89 33 28.5			4.344 85
2	Fisher, 1878	91 11 38.2	+16.3	0.0	91 11 54.5	684	....	
6	Fisher, 1891	91 10 30.5	+89.3	+0.5	91 12 00.3	691	14.4	
8	Fisher, mean				91 11 58.8			3.869 32
1	Dunn, 1878	91 21 43.9	+62.8	0.0	91 22 46.7	686	....	
5	Dunn, 1891	91 20 30.1	+69.0	+2.7	91 21 41.8	691	13.4	
6	Dunn, mean				91 21 52.6			4.028 08
7	Sanel Mountain, 1878	89 42 31.6	+32.1	0.0	89 43 03.7	685	....	4.442 73

Observations in 1878 between 12 hours 15 minutes and 4 hours 40 minutes p. m.; in 1891 between 11 hours 15 minutes a. m. and 1 hour 15 minutes p. m.

Mount Sanhedrin. September and October, 1880. Vertical Circle, No. 37. J. F. Pratt, observer; A. F. Rogers, chief of party. September, 1891. Vertical Circle, No. 80. F. Westdahl, observer; E. F. Dickins, chief of party.

Number of days.	Object observed.		Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ.	P.	T (Cent.)	Log s.
			° ′ ″	″	″	° ′ ″	mm.	°	
14	Cold Spring,	1880	91 09 56·2	+ 2·3	0·0	91 09 58·5	610	17·2	
7	Cold Spring,	1891	91 09 50·7	+ 2·6	+0·4	91 09 53·7	603	18·3	
21	Cold Spring, mean					91 09 56·9			4·819 82
12	King Peak,	1880	90 45 37·8	+ 0·5	0·0	90 45 38·3	610	17·3	5·053 73
16	Paxton,	1880	91 13 20·5	+16·9	0·0	91 13 37·4	610	14·0	4·664 44
15	Two Rock,	1880	91 51 18·9	+16·8	0·0	91 51 35·7	610	13·9	4·539 63
16	Cahto,	1880	90 54 55·4	+12·1	0·0	90 55 07·5	610	14·1	4·659 20
8	Mount Lassic,	1880	90 26 25·3	0·0	0·0	90 26 25·3	610	15·7	4·995 27
10	Great Caspar,	1880	91 44 31·7	+145·7	0·0	91 46 57·4	610	15·7	4·757 12
7	Mount Helena,	1891	90 42 36·3	+ 1·7	0·0	90 42 38·0	603	18·2	5·009 24
8	Snow Mountain West,	1891	89 40 24·5	+ 5·6	+0·7	89 40 30·8	603	18·2	4·517 09
5	Ross Mountain,	1891	91 03 06·5	+ 1·8	0·0	91 03 08·3	603	17·9	5·050 02

Observations in 1880 mostly between 9 hours a. m. and 1 hour 20 minutes p. m.; in 1891 between noon and 1 hour 5 minutes p. m.

Two Rock. November, 1879. Vertical Circle, No. 37. D. B. Wainwright, observer; A. F. Rogers, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	Log s.
6	Paxton	89 40 49·4	+29·8	0·0	89 41 19·2	..	....	4·441 25
6	Cold Spring	90 08 32·1	+24·7	0·0	90 08 56·8	...	....	4·582 89
6	Great Caspar	91 13 24·3	+383·3	0·0	91 19 47·6	...	....	4·376 28
6	Mount Sanhedrin	88 23 34·4	+22·1	0·0	88 23 56·5	...	....	4·539 63
2	Cahto	89 26 46·8	+43·3	0·0	89 27 30·1	...	....	4·578 05

Observations between 9 hours 10 minutes a. m. and 2 hours 30 minutes p. m.

Sulphur Peak. September and October, 1859. Vertical Circle, No. 28. G. Davidson, A. T. Mosman, observers; G. Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	Log s.
4	Sonoma	90 34 55·5	− 0·3	0·0	90 34 55·2	...	....	4·735 45
5	Ross Mountain	90 43 43·1	0·0	0·0	90 43 43·1	...	....	4·573 23
2	Tomales Bay	90 59 23·5	− 0·6	0·0	90 59 22·9	...	....	4·815 06
3	Walalla	90 35 52·1	− 0·5	0·0	90 35 51·6	...	....	4·760 50
4	Sanel Mountain	90 11 15·7	+17.4	0·0	90 11 33·1	...	....	4·582 20
1	Mount Helena, land survey station	89 21 39·9	−14·5	0·0	89 21 25·4	...	....	4·327

Observations between 8 hours 25 minutes a. m. and 6 hours 1 minute p. m.

Sanel Mountain. July and August, 1878. Vertical Circle, No. 37. B. A. Colonna, observer and chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	Log s.
4	Ross Mountain	90 35 43·0	− 2·1	0·0	90 35 40·9	...	....	4·698 23
1	Walalla	90 50 40·4	+10·4	0·0	99 50 50·8	...	....	4·421 47
4	Cold Spring	90 29 40·7	−11·6	0·0	90 29 29·1	...	....	4·442 73
3	Paxton	90 02 16·0	+26·4	0·0	90 02 42·4	...	....	4·349 15
4	Sulphur Peak	90 05 59·4	− 0·2	0·0	90 05 59·2	...	....	4·582 20

Observations between 9 hours 25 minutes a. m. and 5 hours 49 minutes p. m.

Walalla. August, 1878. Vertical Circle, No. 37. B. A. Colonna, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ	P.	T (Cent.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
5	Cold Spring	89 34 40·9	−17·8	0·0	89 34 23·1	...	....	4·267 79
3	Paxton	89 31 49·6	+16·3	0·0	89 32 05·9	...	....	4·542 67
5	Sanel Mountain	89 20 10·8	+16·7	0·0	89 20 27·5	...	....	4·421 47
6	Sulphur Peak	89 50 35·1	− 0·3	0·0	89 50 34·8	...	....	4·760 50
4	Ross Mountain	90 11 33·5	− 2·2	0·0	90 11 31·3	...	....	4·707 64

Observations between 1 hour 45 minutes and 4 hours 35 minutes p. m.

Paxton. December, 1878. Vertical Circle, No. 37. B. A. Colonna, E. F. Dickins, observers; B. A. Colonna, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ	P.	T (Cent.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
8	Mount Sanhedrin	89 07 23·9	− 0·3	0·0	89 07 23·6	...	....	4·664 44
10	Two Rock	90 30 40·8	+ 13·1	0·0	90 30 53·9	...	....	4·441 25
9	Great Caspar	91 04 42·9	+196·8	0·0	91 07 59·7	...	....	4·622 93
12	Cold Spring	90 36 06·0	+ 33·8	0·0	90 36 39·8	...	....	4·344 85
12	Walalla	90 43 26·5	+ 18·8	0·0	90 43 45·3	...	....	4·542 67
12	Sanel Mountain	90 06 58·9	+ 23·0	0·0	90 07 21·9	...	....	4·349 15
1	Fisher	90 54 49·4	− 10·2	0·0	90 54 39·2	...	....	4·397 38

Observations between noon and 3 hours 32 minutes p. m.

Great Caspar. November, 1878. Vertical Circle, No. 37. J. F. Pratt, observer; B. A. Colonna, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ	P.	T (Cent.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
5	Chemise Mountain	89 57 29·3	−106·3	0·0	89 55 43·0	...	....	4·895 27
7	Cahto	88 49 02·8	−169·7	0·0	88 46 13·1	...	....	4·604 55
9	Mount Sanhedrin	88 41 22·1	−145·4	0·0	88 38 56·7	...	....	4·757 12
10	Two Rock	88 56 10·9	−333·7	0·0	88 50 37·2	...	....	4·376 28
5	Paxton	89 13 28·9	−182·1	0·0	88 10 26·8	...	....	4·622 93
7	Cold Spring	89 27 06·5	−192·0	0·0	89 23 54·5	...	....	4·594 46

Observations between noon and 3 hours 45 minutes p. m.

Cahto. October and November, 1880. Vertical Circle, No. 37. J. F. Pratt, observer; A. F. Rogers, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ	P.	T (Cent.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
8	Mount Lassic	89 52 51·5	− 0·8	0·0	89 52 50·7	...	....	4·856 83
8	King Peak	90 18 05·9	0·0	0·0	90 18 05·9	...	....	4·844 92
9	Mount Sanhedrin	89 25 07·1	+ 32·4	0·0	89 25 39·5	...	....	4·659 20
6	Two Rock	90 48 59·2	+ 23·9	0·0	90 49 23·1	...	....	4·578 05
6	Cold Spring	90 37 23·5	+ 22·2	0·0	90 37 45·7	...	....	4·868 74
6	Great Caspar	91 28 24·2	+205·7	0·0	91 31 49·9	...	....	4·604 55

Observations between 10 hours a. m. and 3 hours 10 minutes p. m.

3. COMPUTATION OF COEFFICIENT OF REFRACTION.

In deducing the coefficient of refraction m, we must, as usual, make the assumption of equality of angle of refraction at the upper and lower stations, treat the observations of zenith distances as "simultaneous reciprocal," though made in different years and different months, and take m as referring to the hours of the day when the refraction is near its minimum. The coefficient of refraction was computed by the formula—

$$m = 0{\cdot}5 - \rho \frac{\sin 1''}{2s} (\zeta_{\rm I} + \zeta_{\rm II} - 180^\circ)$$

and its relative weight by $p = \frac{n_{\rm I} n_{\rm II}}{n_{\rm I} + n_{\rm II}} \cdot \frac{s^2}{10^{10}}$, where ρ, the radius of curvature, was taken from the table presented on a preceding page. In the following tables the resulting m's are arranged in two groups (a) of stations close to the coast and (b) of stations farther inland.* The values derived from special observations at Ross Mountain and Bodega Head in 1860 and at Mount Diablo and Martinez East in 1880 are included.

Values of the coefficient of refraction, m, coast of California.

(a) *From lines close to the seacoast.*

Stations.	m.	p.	Stations.	m.	p.
Ross Mountain to Tomales Bay*	·110	0·19	Two Rock to Paxton	·090	0·29
Ross Mountain to Sonoma Mountain*	·099	·27	Cold Spring to Paxton	·075	·32
Cahto to Great Caspar	·085	·52	Paxton to Sanel Mountain	·083	·12
Great Caspar to Cold Spring	·084	·45	Cold Spring to Sanel Mountain	·080	·20
Cold Spring to Walalla	·077	·10	Walalla to Sanel Mountain	·102	·06
Walalla to Ross Mountain	·088	·52	Sanel Mountain to Ross Mountain	·077	·55
Ross Mountain to Mount Tamalpais	·083	2·47	Ross Mountain to Bodega Head	·096	·15
Cahto to Two Rock	·087	0·21	Walalla to Paxton	·079	·29
Great Caspar to Two Rock	·093	·21	Paxton to Great Caspar	·092	·57
Two Rock to Cold Spring	·083	·47	Weighted mean from 19 values	·085 4	

* The two values marked by an asterisk were deduced from the approximate expression $m = 0{\cdot}5 - \frac{\rho}{s^2}(\Delta h - s \cot \zeta)$, with the weight $\frac{n}{4} \cdot \frac{s^2}{10^{10}}$.

(*b*) *From lines farther from the coast, but affected by its climate.*

Stations.	*m.*	*p.*	Stations.	*m.*	*p.*
Mount Diablo to Yolo Base SE.	·085	2·16	Two Rock to Mount Sanhedrin	·084	0·51
Vaca to Yolo Base SE.	·076	0·40	Great Caspar to Mount Sanhedrin	·079	1·54
Monticello to Yolo Base SE.	·073	0·55	Mount Sanhedrin to Cold Spring	·072	3·33
Mount Diablo to Yolo Base NW.	·079	2·35	Paxton to Mount Sanhedrin	·079	2·50
Vaca to Yolo Base NW.	·072	0·76	Mount Sanhedrin to Snow Mtn. West	·062	0·43
Monticello to Yolo Base NW.	·073	0·35	Snow Mtn. West to Cold Spring	·072	1·91
Monticello to Vaca	·065	0·40	Ross Mounthin to Snow Mtn. West	·066	4·03
Mount Diablo to Monticello	·072	3·03	Mount Helena to Mount Sanhedrin	·067	3·65
Mount Diablo to Vaca	·076	1·44	Ross Mountain to Mount Sanhedrin	·068	4·20
Monticello to Mount Tamalpais	·069	2·58	Mount Helena to Snow Mtn. West	·064	2·48
Mount Tamalpais to Vaca	·073	1·69	Sanel Mountain to Sulphur Peak	·074	0·29
Mount Diablo to Mouut Tamalpais	·077	1·85	Sulphur Peak to Ross Mountain	·081	0·38
Mocho to Mount Diablo	·081	1·94	Sulphur Peak to Walalla	·074	0·66
Mocho to Mount Tamalpais	·081	3·52	Ross Mountain to Mount Helena	·074	1·57
Mount Helena to Monticello	·077	0·56	Mount Helena to Mount Tamalpais	·077	3·65
Mount Helena to Vaca	·075	1·68	Mount Diablo to Martinez East	·088	0·41
Mount Helena to Mount Diablo	·076	5·92	Mount Diablo to Ross Mountain	·086	7·66
Mount Helena to Cold Spring	·073	2·57	Weighted mean from 36 values	·075 1	
Cahto to Mount Sanhedrin	·077	1·20			

These results are in accordance with the known influence of a coast climate on the atmospheric refraction, which is to increase it. For the 19 lines close to the coast—say within 20 or 30 kilometres of it—we find the value $m = 0{\cdot}085\,4$, whereas farther inland—say within 60 or 90 kilometres—it has diminished to 0·075 1.

4. COMPUTATION AND ADJUSTMENT OF DIFFERENCES OF HEIGHT.

The method of treatment will be the same as that adopted in determining the heights in eastern Colorado, except that in this adjustment only those differences of height derived from *reciprocal* zenith distances will be used.

The difference of the heights $h_{II} - h_{I}$ of two stations at which the reciprocal zenith distances $\zeta_{II}\ \zeta_{I}$ were observed is given by the usual formula—

$$h_{II} - h_{I} = s \tan \tfrac{1}{2}\,(\zeta_{II} - \zeta_{I}) \left[1 + \frac{h_{II} + h_{I}}{2\rho} + \frac{s^2}{12\rho^2} + \dots \right]$$

where s is the horizontal distance at sea level and ρ the radius of curvature in the plane of the measure. The relative weight is taken equal to $\frac{(n_{I}\, n_{II})10^{10}}{(n_{I} + n_{II})s^2}$, where $n_{I}\ n_{II}$ represent the number of days of observation at the two stations, respectively.

In the present case there are 21 stations, for 6 of which the heights are fixed by spirit leveling, leaving 15 heights to be determined. For this purpose we have 51 differences of height from zenith distances, but of these 3 fall out, being already known from spirit leveling. Consequently the number of observation equations is 48, adopting

the method of "indirect observations" in contradistinction to that of conditional observations. The following values for heights of stations were assumed:

	m.		*m.*
Vaca	$730 + x_1$	Cold Spring	$834 + x_9$
Monticello	$932 + x_2$	Paxton	$1\ 037 + x_{10}$
Mount Tamalpais	$790 + x_3$	Snow Mountain West	$2\ 145 + x_{11}$
Mocho	$1\ 247 + x_4$	Mount Sanhedrin	$1\ 884 + x_{12}$
Mount Helena	$1\ 322 + x_5$	Great Caspar	$321 + x_{13}$
Sulphur Peak	$1\ 055 + x_6$	Two Rock	$837 + x_{14}$
Sanel Mountain	$1\ 022 + x_7$	Cahto	$1\ 290 + x_{15}$
Walalla	$673 + x_8$		

The heights of the six fundamental stations are:

	m.		*m.*
Sonoma Mountain	698·56	Mount Diablo	1 173·10
Tomales Bay	205·13	Yolo Base SE.	21·66
Ross Mountain	672·23	Yolo Base NW.	46·66

Resulting differences of height from reciprocal nonsimultaneous zenith distances, as directly computed and as adjusted. (See farther on.)

Stations.	Difference of height— Observed	Adjusted	Discrepancy
	m.	*m.*	*m.*
Mount Diablo to Yolo Base SE.	1 146·53	*1 151·44	(4·91)
Vaca to Yolo Base SE.	708·06	708·09	0·03
Monticello to Yolo Base SE.	910·32	910·73	0·41
Mount Diablo to Yolo Base NW.	1 119·92	*1 126·44	(6·52)
Vaca to Yolo Base NW.	682·87	683·09	0·22
Monticello to Yolo Base NW.	885·69	885·73	0·04
Monticello to Vaca	202·24	202·63	0·39
Mount Diablo to Monticello	236·28	240·71	4·43
Mount Diablo to Vaca	445·90	443·35	2·55
Monticello to Mount Tamalpais	142·70	141·65	1·05
Mount Tamalpais to Vaca	59·81	60·98	1·17
Mount Diablo to Mount Tamalpais	387·46	382·36	5·10
Mocho to Mount Diablo	74·75	73·85	0·90
Mocho to Mount Tamalpais	449·69	456·21	6·52
Mount Helena to Monticello	389·63	389·70	0·07
Mount Helena to Vaca	590·87	592·33	1·46
Mount Helena to Mount Diablo	147·68	148·98	1·30
Mount Helena to Mount Tamalpais	529·70	531·35	1·65
Mount Diablo to Ross Mountain	491·38	*500·87	(9·49)
Mount Tamalpais to Ross Mountain	127·08	118·51	8·57
Mount Helena to Ross Mountain	649·53	649·85	0·32
Snow Mountain West to Mount Helena	821·32	823·58	2·26
Snow Mountain West to Ross Mountain	1 473·38	1 473·43	0·05
Mount Helena to Cold Spring	492·82	488·12	4·70
Snow Mountain West to Cold Spring	1 315·46	1 311·69	3·77
Snow Mountain West to Mount Sanhedrin	260·87	261·04	0·17
Mount Sanhedrin to Mount Helena	557·32	562·54	5·22
Mount Sanhedrin to Ross Mountain	1 206·42	1 212·39	5·97
Mount Sanhedrin to Cold Spring	1 051·37	1 050·65	0·72
Two Rock to Cold Spring	3·54	3·63	0·09
Mount Sanhedrin to Two Rock	1 046·87	1 047·03	0·16
Sulphur Peak to Ross Mountain	383·93	382·32	1·61
Sanel Mountain to Ross Mountain	352·66	349·79	2·87
Sulphur Peak to Sanel Mountain	30·93	32·53	1·60
Walalla to Ross Mountain	2·91	1·30	1·61
Sulphur Peak to Walalla	379·46	381·02	1·56
Sanel Mountain to Walalla	347·02	348·49	1·47
Sanel Mountain to Cold Spring	187·17	188·06	0·89
Cold Spring to Walalla	160·89	160·44	0·45
Paxton to Sanel Mountain	15·14	15·13	0·01
Paxton to Walalla	363·67	363·62	0·05
Paxton to Cold Spring	203·38	203·18	0·20
Mount Sanhedrin to Paxton	848·12	847·47	0·65
Cold Spring to Great Caspar	513·67	513·10	0·57
Paxton to Great Caspar	717·70	716·29	1·41
Mount Sanhedrin to Great Caspar	1 563·82	1 563·76	0·06
Paxton to Two Rock	199·21	199·56	0·35
Two Rock to Great Caspar	516·15	516·73	0·58
Mount Sanhedrin to Cahto	593·86	594·46	0·60
Cahto to Great Caspar	969·37	969·30	0·07
Cahto to Two Rock	450·87	452·57	1·70

* Values resulting from spirit leveling.

Observation equations and their weights.

$0=+0.28+x_1$	49.3	$0=-9.31+x_3$	6.3	$0=+2.54+x_6-x_8$	6.0
$0=+0.02+x_2$	29.0	$0=+0.24+x_5$	34.6	$0=-1.98+x_7-x_8$	12.0
$0=+0.47+x_1$	32.9	$0=+1.68+x_{11}-x_5$	6.2	$0=+0.83+x_7-x_9$	33.2
$0=-0.35+x_2$	50.7	$0=-0.61+x_{11}$	3.8	$0=+0.11+x_9-x_8$	84.9
$0=-0.24+x_2-x_1$	32.5	$0=-4.82+x_5-x_9$	4.6	$0=-0.14+x_{10}-x_7$	48.1
$0=-4.82+x_2$	4.6	$0=-4.46+x_{11}-x_9$	5.5	$0=+0.33+x_{10}-x_8$	19.7
$0=+2.80+x_1$	13.8	$0=+0.13+x_{11}-x_{12}$	37.0	$0=-0.38+x_{10}-x_9$	131.8
$0=-0.70-x_2-x^3$	4.0	$0=+4.68+x_{12}-x_5$	3.4	$0=-1.12+x_{12}-x_{10}$	55.0
$0=+0.19+x_3-x_1$	8.2	$0=+5.35+x_{12}$	2.6	$0=-0.67+x_9-x_{13}$	18.9
$0=+4.36+x_3$	14.1	$0=-1.37+x_{12}-x_9$	17.5	$0=-1.70+x_{10}-x_{13}$	18.2
$0=-0.85+x_4$	21.3	$0=-0.54+x_{14}-x_9$	22.0	$0=-0.82+x_{12}-x_{13}$	14.5
$0=+7.31+x_4-x_3$	3.0	$0=+0.13+x_{12}-x_{14}$	35.7	$0=+0.79+x_{10}-x_{14}$	49.2
$0=+0.37+x_5-x_2$	25.1	$0=-1.16+x_6$	19.5	$0=-0.15+x_{14}-x_{13}$	66.2
$0=+1.13+x_5-x_1$	14.9	$0=-2.89+x_7$	8.9	$0=+0.14+x_{12}-x_{15}$	27.7
$0=+1.22+x_5$	4.4	$0=+2.07+x_6-x_7$	13.7	$0=-0.37+x_{15}-x_{13}$	20.0
$0=+2.30+x_5-x_3$	7.8	$0=-2.14+x_8$	7.7	$0=+2.13+x_{15}-x_{14}$	10.5

The formation and solution of the normal equations gave the following results:

$x_1=-0.247$	$x_6=-0.449$	$x_{11}=+0.659$
$x_2=+0.386$	$x_7=+0.021$	$x_{12}=+0.620$
$x_3=+0.736$	$x_8=+0.529$	$x_{13}=-0.139$
$x_4=-0.055$	$x_9=-0.034$	$x_{14}=+0.593$
$x_5=+0.083$	$x_{10}=+0.151$	$x_{15}=+0.164$

Resulting heights.

	m.	*m.*	*Feet.*		*m.*	*m.*	*Feet.*
Vaca	729.75	±0.50	2 394.2	Cold Spring	833.97	±0.95	2 736.1
Monticello	932.39	0.51	3 059.0	Paxton	1 037.15	0.96	3 402.7
Mount Tamalpais	790.74	0.91	2 594.3	Snow Mountain West	2 145.66	1.14	7 039.5
Mocho	1 246.94	1.18	4 091.0	Mount Sanhedrin	1 884.62	0.99	6 183.1
Mount Helena	1 322.08	0.62	4 337.5	Great Caspar	320.86	1.09	1 052.7
Sulphur Peak	1 054.55	1.04	3 459.8	Two Rock	837.59	1.05	2 748.0
Sanel Mountain	1 022.02	0.97	3 353.1	Cahto	1 290.16	±1.24	4 232.8
Walalla	673.53	±0.99	2 209.7				

The probable error of an observation of unit weight equals—

$$0.674\sqrt{\frac{[pdd]}{n-c}}=\pm 5.81 \text{ metres}$$

and the probable error of a resulting height $=5.81\sqrt{(\text{reciprocal of weight coefficient})}$.

D. HOURLY OBSERVATIONS OF ZENITH DISTANCES FOR ATMOSPHERIC REFRACTION OVER THE LINE JACKSON BUTTE, AMADOR COUNTY, AND ROUND TOP, ALPINE COUNTY, CALIFORNIA, WITH CORRESPONDING METEOROLOGICAL OBSERVATIONS. BY G. DAVIDSON, ASSISTANT, IN SEPTEMBER AND OCTOBER, 1879.

[Reported by C. A. SCHOTT, Assistant, June, 1884.]

1. INTRODUCTORY REMARKS.

In connection with similar observations on the Pacific coast undertaken by the same observer three years before, it appeared desirable, for the study of the changes in refraction under different climatic conditions, to extend these researches by new observations to a locality in or near the San Joaquin Valley. Jackson Butte Station is on one of the foothills on the western slope of the Sierra Nevada, about 714 metres (2 342 feet) above sea level, while Round Top is one of the primary stations on the crest of the Sierra at an elevation of about 3 173 metres (10 410 feet). The western flank of the Sierra is sparsely timbered, and patches of snow are found near the top. The two stations are distant about 72·4 kilometres (45 statute miles). At Jackson Butte the observations were made by J. F. Pratt, sub-Assistant; at Round Top by G. Davidson and J. J. Gilbert, Assistants. The distance and geographic position of the butte became known from horizontal angles measured there and at Round Top, whence we derive the following results: *

Round Top, latitude, 38° 39′ 43″·06; longitude, 120° 00′ 02″·24.
Jackson Butte, latitude, 38° 20′ 17″·62; longitude, 120° 43′ 14″·73.
Distance $s = 72\ 372{\cdot}6$ metres and $\log s = 4{\cdot}859\ 574$.
Azimuth, Jackson Butte to Round Top, 240° 00′ 19″; reverse azimuth, 60° 27′ 13″.

2. OBSERVATIONS AT ROUND TOP.

The hourly observations made here were intended to be simultaneous with those at Jackson Butte, *weather permitting*. They commence with September 8 and terminate with October 5, comprising fourteen days on which observations were made. A hiatus exists between September 18 and October 2. The angular measures were taken with Gambey vertical circle No. 80 (of 25-centimetre, or 10-inch, diameter), which reads by four verniers to 3″ each; one division of the level equals 3″·56. Each set of hourly observations consists of three repetitions of the double zenith distance, inclusive of four sets of level readings, one-half with circle "right" and one-half with circle "left." Two such measures were taken, one a few minutes before, the other a few minutes after, the full (local) hour. The axis of the vertical circle was 1·292 metres above the bolt, or station, mark and 4·05 metres (13·3 feet) farther removed from Jackson Butte than this station mark. At Round Top the heliotrope stood directly in line, but 2·896 metres in front of the station and 0·317 metre above top of bolt; the lantern when used stood off the line 10·698 metres from center of station and subtending an angle of

* The figures have not been changed from those given in 1884, any small differences from later measures or adjustments being here of no consequence.

29° 07′. The corresponding shortening of the line between the stations equals 9·346 metres; the lantern was 4·020 metres below the station mark. The observed zenith distances required the correction $-0''\cdot83$.

3. OBSERVATIONS AT JACKSON BUTTE.

The corresponding measures of zenith distances at this station were similar to those at the opposite station. The Gambey and Fauth vertical circle No. 111 was used. It reads to 5″ by each of four verniers, and one division of level equals $1''\cdot03$. Aperture of telescope, 65 millimetres. The axis of the vertical circle was 1·62 metres above the station, or top of copper bolt, and the instrument was mounted directly over it. The heliotrope and lantern were 1 metre above the station mark, or bolt, the former in line, but 4·936 metres nearer to Round Top, the latter out of line and 4·150 metres nearer to Round Top. The corrections to the observed zenith distances were, in the case of the heliotrope—

$$\frac{-1\cdot62 + 0\cdot317}{(72\ 372\cdot6 - 2\cdot9)\sin 1''} = -3''\cdot7$$

and in the case of the lantern—

$$\frac{-1\cdot62 - 4\cdot02}{(72\ 372\cdot6 - 9\cdot3)\sin 1''} = -16''\cdot1$$

Some observations of zenith distances of station Pine Hill needed a correction for 1·62 metres elevation at Jackson Butte and for 1·38 metres elevation above station mark, or surface rock of the heliotrope, at Pine Hill. Total correction $-1''\cdot03$, the distance being 48 224 metres very nearly.

Communication between the observers was kept up by means of preconcerted heliotrope and lamp signals. Between 6 a. m. and 6 p. m. the observations were made on heliotropes. Reductions and corrections to the meteorological instruments are referred to further on.

4. ROUND TOP, 1879.

Resulting zenith distances of Jackson Butte reduced to station mark (top of bolt) at both stations.

$\zeta = 92° \; 13' +$

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
	″	″	″	″	″	″	″
1 a. m.	.	.	.	38·6	.	.	.
2	.	.	.	41·2	.	.	.
3	.	.	.	.	.	.	.
4	.	.	.	.	.	.	.
5	.	.	.	40·8	.	.	.
6	37·3	30·9	36·6	47·7	60·2	56·8	55·8
7	37·5	30·6	30·8	53·0	62·7	57·8	54·4
8	52·3	49·3	45·0	55·0	63·6	59·7	59·7
9	59·0	61·2	57·4	62·1	64·5	62·4	63·5
10	64·5	68·3	62·0	60·7	65·5	63·2	61·5
11	68·2	68·4	67·0	65·5	66·6	66·8	65·7
Noon	66·8	68·0	67·1	73·7	75·0	68·3	67·5
1 p. m.	71·1	69·1	68·6	73·4	71·4	70·9	[65·6]
2	71·2	69·8	70·2	72·0	70·4	69·8	64·8
3	73·7	70·3	69·2	73·2	72·2	73·1	[65·8]
4	72·4	68·5	66·4	73·8	73·2	72·5	[65·5]
5	65·4	66·0	60·7	73·8	73·9	71·6	[61·9]
6	53·8	44·3	53·5	71·3	71·0	66·0	[55·4]
7	.	39·0	21·9	.	.	.	.
8	.	23·9	06·4	.	.	.	.
9	.	.	11·0	.	.	.	.
10	.	.	10·8	.	.	.	.
11	.	.	14·4	.	.	.	.
Midnight	.	.	24·4	.	.	.	.

Resulting zenith distances of Jackson Butte, etc.—Continued.

$\zeta = 92° \; 13' +$ (Continued.)

Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.
	″	″	″	″	″	″	″
1 a. m.	.	.	.	.	49·5	.	46·3
2	.	.	.	.	52·5	.	42·9
3	.		.	.	59·2	.	42·0
4	.	.	.	.	56·3	.	42·4
5	.	.	.	.	52·8	.	43·8
6	55·3	63·0	64·0	37·5	60·3	56·2	49·1
7	51·2	61·2	65·6	31·1	59·7	56·4	46·4
8	48·6	64·2	66·8	48·0	63·0	58·7	48·8
9	63·5	66·2	69·4	54·9	62·5	68·0	57·2

Resulting zenith distances of Jackson Butte, etc.—Completed.

$\zeta = 92° 13' +$ (Completed.)

Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.
	″	″	″	″	″	″	″
10 a. m.	65 ·1	67 ·6	65 ·2	64 ·6	68 ·8	71 ·3	55 ·9
11	[67 ·5]	67 ·9	67 ·8	67 ·0	69 ·4	69 ·4	61 ·8
Noon	70 ·2	78 ·0	70 ·1	69 ·7	70 ·2	69 ·9	63 ·8
1 p. m.	[70 ·1]	70 ·6	68 ·6	71 ·2	70 ·7	70 ·7	65 ·0
2	[71 ·1]	73 ·5	79 ·5	70 ·6	70 ·4	72 ·3	64 ·9
3	[72 ·1]	76 ·6	77 ·7	71 ·8	69 ·6	[74 ·0]	65 ·2
4	[71 ·8]	77 ·6	78 ·3	71 ·8	70 ·8	74 ·5	63 ·2
5	[68 ·2]	75 ·2	73 ·2	67 ·3	70 ·6	62 ·4	[59 ·6]
6	[61 ·7]	74 ·2	73 ·6	60 ·7	[64 ·1]	[55 ·9]	[53 ·1]
7	.	.	.	63 ·3	.	40 ·4	.
8	.	.	.	58 ·0	.	36 ·3	.
9	.	.	.	58 ·7	.	24 ·0	.
10	.	.	.	53 ·0	.	37 ·0	.
11	.	.	.	[48 ·9]	.	37 ·4	.
Midnight	.	.	.	51 ·7	.	45 ·2	.

The results from observations at 7 and 8 p. m. on September 9, and at 1, 2, and 5 a. m. on September 11, are not used, as there were no corresponding observations at Jackson Butte. The values in brackets were obtained by interpolation, as explained below.

5. DIURNAL VARIATION OF THE ZENITH DISTANCE.

The method adopted to obtain a homogeneous series of hourly means is as follows: For the hours at which observations were made on each of the 14 days the mean values are taken directly. For the other hours from 6 a. m. to 6 p. m., the missing values are obtained by comparing the observations at those hours on the other days with the next hour. For example, to interpolate a value for 2 p. m., September 15, the average change between that hour and noon for the 13 other days is applied to the tabular value for noon, September 15. The value for 11 p. m., October 2, is also obtained in this way. In order to reduce the hourly means for 1, 2, 3, 4, and 5 a. m., October 3 and 5, to the same system as for the hours from 6 a. m. to 6 p. m., the difference between the mean of these 13 hours for the whole 14 days, and for October 3 and 5, only is applied to each of the 5 hourly means. The hourly means for the hours from 7 p. m. to midnight are corrected in the same manner and the desired homogeneous series is completed, as shown in the following table:

6. RESULTING HOURLY MEANS OF ZENITH DISTANCES OF JACKSON BUTTE AS OBSERVED AT ROUND TOP.

$\zeta = 92° 13' +$.

Hour.	Seconds of ζ.	n.	$\zeta -$ mean.	Hour.	Seconds of ζ.	n.	$\zeta -$ mean.	Hour.	Seconds of ζ.	n.	$\zeta -$ mean.
	"		"		"		"		"		"
1 a. m.	49·6	2	−5·2	9 a. m.	62·3	14	+ 7·5	5 p. m.	67·8	11	+13·0
2	49·4	2	−5·4	10	64·6	14	+ 9·8	6	61·3	9	+ 6·5
3	52·3	2	−2·5	11	67·1	13	+12·3	7	44·5	3	−10·3
4	51·1	2	−3·7	Noon.	69·9	14	+15·1	8	36·2	3	−18·6
5	50·0	2	−4·8	1 p.m.	69·8	12	+15·0	9	33·8	3	−21·0
6	50·8	14	−4·0	2	70·8	13	+16·0	10	36·2	3	−18·6
7	49·9	14	−4·9	3	71·8	11	+17·0	11 p.m.	36·2	2	−18·6
8 a. m.	55·9	14	+1·1	4 p.m.	71·5	12	+16·7	Midn't	43·0	3	−11·8

Mean $\zeta = 92° 13' 54''·8$.

The number of days of observation is given in columns headed n. The quantities ($\zeta -$ mean) give the observed diurnal variation in zenith distance, which is shown graphically in diagram (1) farther on.

7. JACKSON BUTTE, 1879.

Resulting zenith distances of Round Top deduced to station mark (top of bolt) at both stations.

$\zeta = 88° 19' +$

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
	"	"	"	"	"	"	"
6	43·3	41·0	46·0	63·2	57·9	57·0	47.8
7	45·9	33·8	52·5	60·7	63·1	55·7	59·2
8	45·8	51·0	46·8	54·4	67·4	50·5	56·6
9	57·0	61·6	51·6	71·1	67·4	69·2	68·4
10	[68·4]	74·8	71·8	73·2	82·2	78·3	84·1
11	[81·5]	76·0	82·5	82·6	88·0	88·4	84·8
Noon	83·1	76·6	83·5	84·6	91·6	88·2	85·0
1 p. m.	85·5	80·7	83·0	89·4	92·8	91·0	87·2
2	83·9	84·5	84·2	89·4	91·8	92·8	86·8
3	83·2	82·2	84·0	88·5	91·7	92·0	87·3
4	81·0	82·6	83·5	89·0	88·2	87·7	88·5
5	77·2	80·4	79·2	86·8	89·0	86·9	[84·3]
6	68·4	71·9	72·9	81·5	87·6	82·0	[77·5]
7	.	.	57·6	.	.	.	.
8	.	.	54·1	.	.	.	.
9	.	.	26·8	.	.	.	.
10	.	.	31·8	.	.	.	.
11	.	.	[24·8]	.	.	.	.
Midnight	.	.	[29·9]	.	.	.	.

Resulting zenith distances of Round Top—Completed.

$\zeta = 88° \; 19' +$ (Completed.)

Hour.	Sept. 15	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.
	″	″	″	″	″	″	″
1 a. m.	.	.	.	.	57·1	.	12·1
2	.	.	.	.	54·5	.	05·0
3	.	.	.	.	60·8	.	13·6
4	.	.	.	.	59·8	.	27·3
5	.	.	.	.	51·5	.	20·2
6	64·3	64·5	66·1	[31·6]	41·2	64·4	22·3
7	58·7	46·2	69·7	[30·5]	49·2	49·2	20·4
8	60·7	62·6	75·5	35·1	61·0	66·6	25·8
9	72·8	72·9	80·7	41·3	61·8	73·9	48·1
10	81·5	83·7	87·4	63·0	82·4	80·7	45·4
11	87·8	90·9	93·0	73·1	89·6	91·9	70·6
Noon	86·2	92·4	94·3	82·2	88·8	86·3	80·0
1 p. m.	[88·3]	94·6	94·0	88·1	87·6	89·8	80·0
2	[88·6]	96·8	93·8	86·9	86·3	91·8	78·4
3	[87·6]	93·6	94·1	86·4	87·2	85·8	79·1
4	[86·2]	92·3	93·7	83·6	88·2	84·9	73·3
5	[82·0]	90·7	82·3	77·0	82·8	76·1	[69·1]
6	[75·2]	[83·9]	89·6	50·3	[76·0]	[69·3]	[62·3]
7	.	.	.	55·3	.	50·9	.
8	.	.	.	56·2	.	39·7	.
9	.	.	.	59·4	.	41·8	.
10	.	.	.	54·4	.	63·8	.
11	.	.	.	52·8	.	51·3	.
Midnight	.	.	.	59·8	.	54·6	.

The interpolated values (in brackets) and hourly means are obtained in the manner already explained for the observations at Round Top.

8. RESULTING HOURLY MEANS OF ZENITH DISTANCES OF ROUND TOP AS OBSERVED AT JACKSON BUTTE.

$\zeta = 88° \; 19' +$.

Hour.	Seconds of ζ.	n.	ζ — mean.	Hour.	Seconds of ζ.	n.	ζ — mean.	Hour.	Seconds of ζ.	n.	ζ — mean.
	″		″		″		″		″		″
1 a. m.	42·5	2	−20·1	9 a. m.	64·1	14	+ 1·5	5 p. m.	81·7	11	+19·1
2	37·7	2	−24·9	10	75·5	13	+12·9	6	74·9	8	+12·3
3	45·1	2	−17·5	11	84·3	13	+21·7	7	58·5	3	− 4·1
4	51·5	2	−11·1	Noon	85·9	14	+23·3	8	53·9	3	− 8·7
5	43·7	2	−18·9	1 p. m.	88·0	13	+25·4	9	46·6	3	−16·0
6	50·8	13	−11·8	2	88·3	13	+25·7	10	53·9	3	− 8·7
7	49·6	13	−13·0	3	87·3	13	+24·7	11 p. m.	46·9	2	−15·7
8 a. m.	54·3	14	− 8·3	4 p. m.	85·9	13	+23·3	Mid-night	52·0	2	−10·6

Mean $\zeta = 88° \; 19' \; 62''.6$.

The number of days of observation is given in the columns headed *n*. The quantities (ζ — mean) give the observed diurnal variation in zenith distance, as shown graphically in diagram (2) farther on.

Comparing diagrams (1) and (2) we note the facts:

(a) The diurnal variation in the zenith distance is greater at the lower station than at the upper station, the range at the former being nearly 51″ and at the latter nearly 38″.

(b) The maximum zenith distance is reached between 2 and 3 p. m., and the minimum sometime between 9 p. m. and 2 a. m.

(c) The zenith distance varies but slightly between 11 a. m. and 4½ p. m. The irregularity in the curves during the night hours is due simply to the small number of observations.

Computation of the difference of height Δh and average coefficient of refraction m under the ordinary supposition of equal refraction at the two stations.

The adopted formulæ are—

$$m = 0{\cdot}5 - \frac{\zeta + \zeta' - 180^\circ}{2\,\psi}\quad,\quad \psi = \frac{s}{\rho \sin 1''}$$

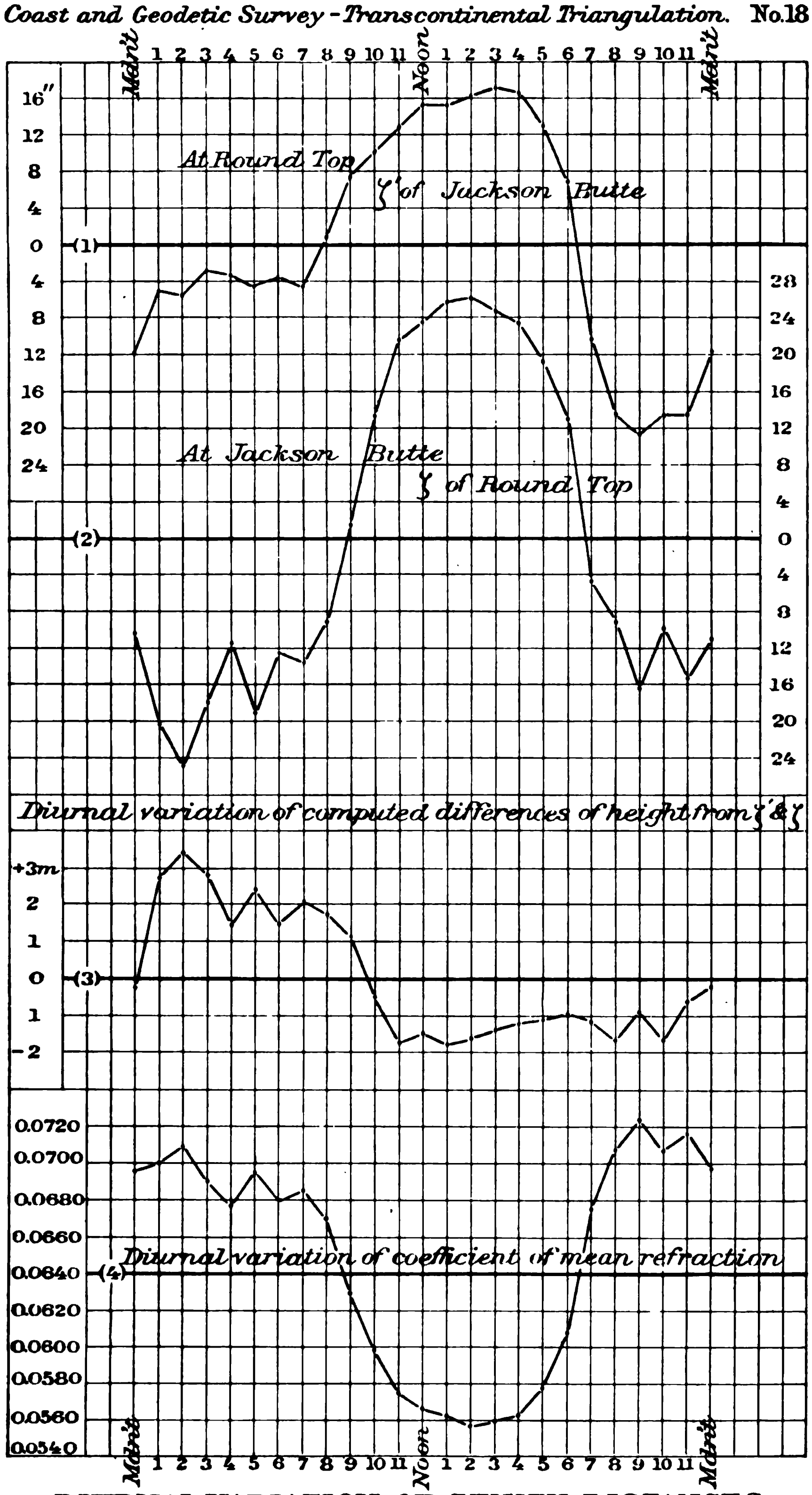
$$\text{and } \Delta h = h' - h = s \tan \tfrac{1}{2}\,(\zeta' - \zeta)\left[1 + \frac{h+h'}{2\,\rho} + \frac{s^2}{12\,\rho^2}\right]$$

For $\phi = 38^\circ 30'$ and $\alpha = 60^\circ 15'$, log $\rho = 6{\cdot}804\ 822$ and $\psi = 2\ 339''{\cdot}8$. Using the approximate values $h = 714m$ and $h' = 3\ 174m$ we get log. quantity in [ ] = 0·000 137. The resulting hourly values for Δh and *m* are given in the following table:

Hour.	Δh.	Difference from mean.	*m*.	Hour.	Δh.	Difference from mean.	*m*.
	m.	*m*.			*m*.	*m*.	
1 a. m.	2 466·11	+2·60	0·070 0	3	2 462·10	− 1·41	·055 7
2	6·89	+3·38	·071 1	4	2·32	− 1·19	·056 1
3	6·11	+2·60	·068 9	5	2·39	− 1·12	·057 7
4	4·78	+1·27	·067 8	6	2·46	− 1·05	·060 6
5	5·97	+2·46	·069 7	7	2·39	− 1·12	·067 7
6	4·85	+1·34	·068 0	8	1·76	− 1·75	·070 5
7	5·55	+2·04	·068 4	9	2·60	− 0·91	·072 5
8	5·13	+1·62	·066 2	10	1·76	− 1·75	·070 5
9	4·53	+1·02	·062 7	11	2·95	− 0·56	·071 9
10	2·95	−0·56	·059 8	Midnight	2 463·27	− 0·24	·069 4
11	1·83	−1·68	·057 4			{+18·33	
Noon	2·04	−1·47	·056 4			{−18·42	
1 p. m.	1·65	−1·86	·056 0	Mean	2 463·51		0·064 6
2	2 461·76	−1·75	·055 7		±0·28		

The values of Δh are plotted on diagram (3) and show the computed difference of height between 10 a. m. and near midnight to be smaller than the mean; but the results for those hours appear remarkably consistent.

The values for coefficient of refraction are plotted on diagram (4) and indicate a well-marked diurnal variation, most regular where the observations were sufficiently



DIURNAL VARIATION OF ZENITH DISTANCES

numerous. The value of *m* is least variable near its minimum, and the best time for observing vertical angles would appear to be between 11½ a. m. and 4½ p. m. The minimum occurs between 2 and 3 p. m., the maximum apparently at 9 p. m.

9. METEOROLOGICAL RECORD IN CONNECTION WITH OBSERVATIONS OF ZENITH DISTANCES.

At Round Top barometer Green No. 2017 was used; index correction + 0·063 inch. The cistern of the barometer was 0·37 metre above the copper bolt; hence correction + 0·001 inch and total correction = + 0·064 inch. There appears to be no corrections for the thermometers.

At Jackson Butte two barometers were used: J. Green, No. 1357, in September, and J. Green, No. 1353, in October. Index correction to No. 1357, from 5 days' comparisons with the Signal Service standard (Adie 1601) at the Merchants' Exchange, San Francisco, = + 0·050 inch, and correction to attached thermometer = − 1°·0; index correction to No. 1353 from 10 days' comparisons at San Francisco = + 0·087 inch, and correction to attached thermometer = − 1°·6. The height of the cisterns of the barometers above the station mark (copper bolt) was 1 metre; corresponding correction = + 0·003 inch. The thermometers required no correction. The records contain no information respecting the shelter of the instruments at the stations..

Atmospheric pressure at Round Top, 1879.

[Mercurial column reduced to 0° C. and referred to station mark. Index correction applied.]
20 inches + tabular quantity.

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
1 a. m.	.	.	.	·730	.	.	.
2	.	.	.	·730	.		.
3	.	.	.	·727	.	.	.
4	.	.	.	·728	.	.	.
5	.	.	.	·742	.	.	.
6	·698	·588	·572	·769	·827	·813	·826
7	·709	·585	·584	·774	·821	·799	·829
8	·709	·594	·595	·770	·831	·795	·836
9	·708	·597	·620	·778	·834	·816	·850
10	·736	·569	·637	·801	·840	·814	·852
11	·724	·565	·640	·804	·838	·818	·854
Noon	·721	·562	·650	·804	·838	·813	·856
1 p. m.	·717	·561	·655	·819	·837	·829	·855
2	·707	·558	·653	·816	·826	·824	·848
3	·684	·543	·670	·816	·827	·817	·859
4	·680	·528	·675	·819	·843	·822	·848
5	·682	·516	·687	·818	·822	·798	[·841]
6	·669	·503	·694	·822	·822	·798	[·838]
7	.	.	·699	.	.	.	.
8	.	·503	·709	.	.	.	.
9	.	.	·715	.	.	.	.
10	.	.	·713	.	.	.	.
11	.	.	·718	.	.	.	.
Midnight	.	.	·719	.	.	.	.

Atmospheric pressure at Round Top, 1879—Completed.

[Mercurial column reduced to 0° C. and referred to station mark. Index correction applied.]
20 inches + tabular quantity.

Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.	Hourly Means.
1 a. m.	.	.	.	.	·742	.	·399	·767
2	.	.	.	.	·735	.	·402	·765
3	.	.	.	.	·727	.	·380	·751
4	.	.	.	.	·726	.	·380	·750
5	.	.	.	.	·723	.	·363	·740
6	·864	·825	·795	·786	·724	·613	·344	·717
7	·869	·814	·792	·753	·724	[·608]	[·345]	·715
8	·870	·821	·797	·787	·724	[·604]	[·345]	·720
9	·872	·823	·804	·785	·730	·599	·346	·726
10	·889	·824	·801	·780	·738	·596	·342	·730
11	[·884]	·821	·808	·779	·735	·592	·336	·728
Noon	·879	·817	·803	·779	·727	·589	·324	·724
1 p. m.	[·878]	·813	·794	·781	·720	·571	·317	·724
2	[·871]	·811	·788	·765	·715	·547	·317	·717
3	[·866]	·820	·782	·761	·708	·528	·296	·713
4	[·862]	·799	·787	·760	[·704]	·498	[·292]	·708
5	[·855]	·794	·783	·758	[·697]	[·486]	[·285]	·702
6	[·852]	·802	·768	·760	[·694]	·475	[·282]	·698
7	.	.	.	·752	.	·458	.	·695
8	.	.	.	·755	.	·443	.	·695
9	.	.	.	·759	.	·447	.	·699
10	.	.	.	·755	.	·448	.	·698
11	.	.	.	[·756]	.	·436	.	·696
Midnight	.	.	.	·756	.	·418	.	·690

The meteorological instruments were read on an average about two minutes before the full hour. The interpolated values (in brackets) and the hourly means were obtained in the manner explained in connection with the zenith distances at Round Top. The values from 1 to 5 a. m., September 11, and 8 p. m., September 9, were not used, there being no corresponding observations at Jackson Butte.

Atmospheric pressure at Jackson Butte, 1879.

[Mercurial column reduced to 0° C. and referred to station mark. Index correction applied.]
27 inches + tabular quantity.

Hour	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
6 a. m.	·634	·547	·535	.627	·698	·685	·699
7	·622	·546	·530	·639	·705	·682	·694
8	·634	·545	·535	·635	·702	·682	·697
9	·648	·558	·543	·683	·705	·701	·710
10	·657	·547	·560	·696	·709	·703	·718
11	·648	·546	·579	·698	·708	·709	·711
Noon	·626	·539	·563	·701	·704	·703	·706
1 p. m.	·611	·536	·551	·689	·696	·697	·701

Atmospheric pressure at Jackson Butte, 1879—Continued.

[Mercurial column reduced to 0° C. and referred to station mark. Index correction applied.]
27 inches + tabular quantity.

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
2 a. m.	·595	·531	·552	·679	·688	·687	·690
3	·591	·516	·551	·672	·677	·679	·683
4	·589	·508	·549	·668	·663	·665	·681
5	·579	·504	·551	·668	·660	·667	·684
6	·587	·505	·560	·677	·660	·672	·681
7	.	.	·570	.	.	.	.
8	.	.	·586	.	.	.	.
9	.	.	·586	.	.	.	.
10	.	.	·593	.	.	.	.
11	.	.	·587	.	.	.	.
Midnight	.	.	[·582]	.	.	.	.

Atmospheric pressure at Jackson Butte, 1879—Completed.

[Mercurial column reduced to 0° C. and referred to station mark. Index correction applied].
27 inches + tabular quantity.

Hour	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.	Hourly means.
1 a. m.	.	.	.	.	·687	.	·545	·672
2	.	.	.	.	·677	.	·536	·662
3	.	.	.	.	·673	.	·506	·645
4	.	.	.	.	·672	.	·505	·644
5	.	.	.	.	·675	.	·496	·641
6	·700	·633	·619	[·728]	·673	·595	·509	·634
7	·689	·622	·613	[·727]	·684	·596	·523	·634
8	·690	·631	·610	·728	·685	·599	·508	·634
9	·695	·644	·631	·736	·696	·598	·541	·649
10	·692	·644	·635	·734	·696	·598	·533	·651
11	·691	·637	·630	·731	·689	·591	·474	·646
Noon	·681	·631	·626	·722	·684	·531	·479	·635
1 p. m.	·671	·619	·617	·713	·659	·504	·469	·624
2	[·662]	·609	·613	·702	·650	·501	·443	·614
3	[·655]	·604	·609	·699	·635	·497	·435	·607
4	[·648]	·603	·604	·692	·631	·495	·414	·601
5	[·647]	·605	·604	·686	·630	·491	[·413]	·599
6	[·650]	·614	·591	·686	[·633]	·499	[·416]	·602
7	.	.	.	·696	.	·504	.	·611
8	.	.	.	·696	.	·516	.	·621
9	.	.	.	·692	.	·506	.	·616
11	.	.	.	·691	.	·496	.	·615
11'	.	.	.	·688	.	·475	.	·605
Midnight	.	.	.	·683	.	·530	.	·620

Meteorological instruments read about ten minutes before the full hour. The interpolated values (in brackets) and the hourly means were obtained in the manner explained for the zenith distances at Round Top.

Atmospheric temperature at Round Top, 1879.

[Dry bulb thermometer with Fahrenheit scale.]

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
	°	°	°	°	°	°	°
1 a.m.	.	.	.	45·2	.		.
2	.	.	.	46·7	.	.	.
3	.	.	.	46·2	.	.	.
4	.	.	.	45·6	.	.	.
5	.	.	.	44·9	.	.	.
6	45·4	38·2	40·7	48·9	47·6	47·7	47·8
7	46·6	38·8	44·6	50·8	49·5	49·7	49·7
8	42·8	40·9	44·7	51·2	51·4	50·8	50·1
9	49·8	42·8	46·4	52·7	53·8	52·8	53·4
10	50·9	45·7	51·2	53·6	55·1	54·6	55·8
11	52·8	47·7	51·4	54·9	57·3	54·8	57·3
Noon	53·8	48·6	53·4	56·8	59·8	56·6	58·6
1 p.m.	54·8	49·2	54·6	58·3	60·4	57·6	60·2
2	55·3	49·6	54·2	60·4	61·3	58·0	61·0
3	54·9	49·2	56·9	58·8	60·6	58·6	61·7
4	53·7	47·7	57·4	59·7	59·9	57·9	61·9
5	51·8	45·8	57·2	57·7	60·5	56·6	[60·0]
6	48·6	42·2	48·4	54·8	53·7	53·2	[55·9]
7	.	40·5	46·6	.	.	.	.
8	.	39·8	43·4	.	.	.	.
9	.	.	44·3	.	.	.	.
10	.	.	44·8	.	.	.	.
11	.	.	46·4	.	.	.	.
Midnight	.	.	45·3	.	.	.	.

Atmospheric temperature at Round Top, 1879—Continued.

[Dry bulb thermometer with Fahrenheit scale.]

Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.	Hourly means.
	°	°	°	°	°	°	°	°
1 a.m.	.	.	.	.	40·4	.	35·4	48·51
2	.	.	.	.	40·3	.	34·4	47·96
3	.	.	.	.	40·2	.	34·7	48·06
4	.	.	.	.	39·8	.	32·8	46·91
5	.	.	.	.	39·9	.	31·7	46·41
6	50·2	49·9	47·3	44·2	39·3	39·0	30·1	44·02
7	51·3	53·4	47·8	46·0	40·8	[40·7]	[31·2]	45·78
8	52·2	55·3	48·4	45·8	42·5	[42·3]	[32·4]	46·48
9	53·9	55·8	54·3	47·8	43·9	44·0	33·5	48·92
10	57·3	57·7	56·6	47·9	47·1	44·4	34·4	50·88
11	[59·0]	60·2	57·9	50·2	48·6	46·7	36·2	52·50
Noon	60·8	63·2	61·2	51·2	50·1	48·2	37·0	54·24
1 p.m.	[61·4]	62·6	58·4	53·0	51·3	49·0	37·1	54·85

Atmospheric temperature at Round Top, 1879—Completed.

[Dry bulb thermometer with Fahrenheit scale.]

Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.	Hourly means.
	°	°	°	°	°	°	°	°
2	[61·1]	58·7	55·4	52·8	51·2	48·7	35·7	54·53
3	[60·9]	57·6	56·4	52·2	51·1	47·8	34·1	54·34
4	[60·6]	59·7	54·8	[50·2]	[50·8]	47·9	[33·8]	54·00
5	[58·7]	54·8	52·8	48·2	[48·9]	[44·6]	[31·9]	52·11
6	[54·6]	52·4	49·8	45·0	[44·8]	41·3	[27·8]	48·04
7	.	.	.	42·0	.	39·7	.	45·38
8	.	.	.	41·7	.	39·1	.	44·01
9	.	.	.	41·3	.	38·3	.	43·91
10	.	.	.	40·8	.	37·8	.	43·74
11	.	.	.	[40·9]	.	36·0	.	43·71
Midnight	.	.	.	41·0	.	35·9	.	43·34
							Mean	48·44

The interpolated values (in brackets) and the hourly means were obtained in the manner explained for the zenith distances at Round Top. The values for 1 to 5 a. m. September 11, and 7 and 8 p. m. September 9, are not used as there were no corresponding observations at Jackson Butte.

Atmospheric temperature at Jackson Butte, 1879.

[Dry bulb thermometer with Fahrenheit scale.]

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
	°	°	°	°	°	°	°
6 a. m.	65·0	67·2	61·8	72·1	76·9	72·9	75·8
7	69·0	70·0	66·8	74·9	77·4	76·2	79·9
8	67·8	70·1	67·8	75·9	83·8	78.2	81·0
9	68·0	66·0	67·2	76·6	84·2	80·9	80·4
10	71·0	68·5	72·8	79·2	84·1	84·4	81·9
11	76·0	71·8	75·0	81·9	87·0	84·8	83·0
Noon	77·5	74·8	76·9	82·8	88·6	87·8	85·1
1 p. m.	79·4	75·9	80·5	85·0	90·8	90·2	85·0
2	80·0	76·9	80·0	87·9	90·3	90·8	89·0
3	79·5	78·9	82·0	88·0	91·9	90·5	91·2
4	81·0	78·7	82·3	89·0	92·5	89·2	90·5
5	78·4	78·7	82·2	88·8	90·0	87·6	87·5
6	73·8	74·9	76·9	83·3	85·1	83·5	83·0
7	.	.	73·5	.	.	.	.
8	.	.	73·0	.	.	.	.
9	.	.	73·8	.	.	.	.
10	.	.	72·0	.	.	.	.
11	.	.	71·8	.	.	.	.
Midnight	.	.	[70·6]	.	.	.	.

Atmospheric temperature at Jackson Butte, 1879—Completed.

[Dry bulb thermometer with Fahrenheit scale.]

Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.	Hourly mean.
	°	°	°	°	°	°	°	°
1 a. m.	.	.	.	.	72 ·0	.	53.0	73 ·24
2	.	.	.	.	73 ·0	.	51 ·0	72 ·74
3	.	.	.	.	74 ·0	.	51 ·5	73 ·49
4	.	.	.	.	69 ·0	.	51 ·8	71 ·14
5	.	.	.	.	72 ·8	.	52 ·8	73 ·54
6	79 ·5	80 ·2	76 ·5	[66 ·7]	72 ·5	73 ·8	50 ·3	70 ·80
7	83 ·6	83 ·2	82 ·0	[69 ·4]	74 ·0	73 ·2	50 ·0	73 ·54
8	88 ·3	84 ·8	84 ·2	71 ·6	78 ·5	76 ·2	52 ·0	75 ·73
9	85 ·2	88 ·3	88 ·2	72 ·8	82 ·2	77 ·1	52 ·8	76 ·42
10	87 ·4	89 ·2	90 ·0	76 ·2	81 ·0	78 ·9	56 ·7	78 ·66
11	88 ·0	90 ·8	92 ·0	80 ·8	82 ·5	80 ·0	60 ·8	81 ·03
Noon	89 ·2	93 ·0	93 ·0	83 ·0	83 ·2	83 ·2	62 ·2	82 ·88
1 p. m.	91 ·0	96 ·0	96 ·2	84 ·9	83 ·9	83. 2	64 ·9	84 ·78
2	[91 ·8]	96 ·2	96 ·0	86 ·7	84 ·9	83 ·2	64 ·9	85 ·61
3	[92 ·1]	96 ·8	95 ·0	84 ·9	87 ·3	82 ·0	63 ·3	85 ·96
4	[91 ·5]	96 ·9	93 ·5	85 ·7	85 ·0	79 ·1	60 ·6	85 ·39
5	[89 ·1]	93 ·0	89 ·9	82 ·6	82 ·3	74 ·1	[58 ·2]	83 ·03
6	[83 ·8]	86 ·5	84 ·0	75 ·8	[77 ·0]	67 ·9	[52 ·9]	77 ·74
7	.	.	.	74 ·0	.	65 ·0	.	73 ·89
8	.	.	.	75 ·0	.	60 ·4	.	72 ·53
9	.	.	.	75 ·8	.	63 ·2	.	73 ·99
10	.	.	.	75 ·0	.	64 ·0	.	73 ·39
11	.	.	.	74 ·0	.	63 ·6	.	72 ·86
Midnight	.	.	.	74 ·2	.	61 ·0	.	71 ·66
							Mean	76 ·83

The interpolated values (in brackets) and the hourly means were obtained in the manner explained for the zenith distances at Round Top.

Atmospheric moisture at Round Top, 1879.

[Wet bulb thermometer with Fahrenheit scale.]

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
	°	°	°	°	°	°	°
1 a. m.	.	.	.	34 ·9	.	.	.
2	.	.	.	38 ·3	.	.	.
3	.	.	.	38 ·7	.	.	.
4	.	.	.	37 ·8	.	.	.
5	.	.	.	38 ·2	.	.	.
6	32 ·7	30 ·8	32 ·7	37 ·2	37 ·7	37 ·6	37 ·9
7	33 ·4	31 ·6	33 ·3	37 ·3	39 ·6	39 ·3	39 ·4
8	33 ·9	33 ·4	35 ·7	38 ·-	40 ·8	40 ·8	40 ·1
9	36 ·8	34 ·3	36 ·3	39 ·2	41 ·7	41 ·6	41 ·8

Atmospheric moisture at Round Top, 1879—Continued.

[Wet bulb thermometer with Fahrenheit scale.]

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
	°	°	°	°	°	°	°
10 a. m.	37·8	34·8	38·6	39·6	42·8	41·2	43·2
11	39·8	37·7	41·8	40·3	43·5	42·0	48·2
Noon	40·3	37·6	43·7	41·5	44·9	43·4	44·3
1 p. m.	41·6	39·1	45·0	42·6	44·9	44·7	44·6
2	46·0	39·6	42·7	43·6	46·3	44·4	45·1
3	40·8	39·8	46·8	44·7	46·6	45·6	46·6
4	39·8	39·7	48·2	45·4	47·6	45·3	46·1
5	38·2	38·9	47·1	43·6	48·9	43·9	.
6	37·7	35·4	39·2	43·0	44·4	42·6	.
7	.	33·4	38·4	.	.	.	.
8	.	32·2	35·4	.	.	.	.
9	.	.	35·6	.	.	.	.
10	.	.	35·9	.	.	.	.
11	.	.	36·7	.	.	.	.
Midnight	.	.	34·6	.	.	.	.

Atmospheric moisture at Round Top, 1879—Completed.

[Wet bulb thermometer with Fahrenheit scale.]

Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.
	°	°	°	°	°	°	°
1 a. m.	.	.	.	.	30·9	.	31·7
2	.	.	.	.	30·7	.	30·2
3	.	.	.	.	30·3	.	29·6
4	.	.	.	.	30·0	.	29·0
5	.	.	.	.	30·0	.	31·7
6	36·8	36·5	34·2	30·1	29·8	31·3	28·1
7	38·1	39·8	34·9	31·9	32·7	.	.
8	39·4	42·1	36·3	32·6	33·5	.	.
9	39·4	42·7	41·9	33·8	34·2	34·8	30·2
10	42·8	45·2	43·2	34·9	36·4	34·3	30·7
11	.	45·2	44·2	36·3	37·2	35·2	31·8
Noon	46·4	44·9	45·9	43·7	38·9	37·1	32·2
1 p. m.	.	46·8	43·7	37·9	39·2	37·3	32·4
2	.	43·5	39·4	38·6	39·0	38·7	32·7
3	.	43·3	41·4	37·8	39·0	37·7	32·4
4	.	45·4	39·9	.	.	36·8	.
5	.	40·6	39·0	35·3	.	.	.
6	.	37·6	37·4	33·8	.	33·7	.
7	.	.	.	32·7	.	33·4	.
8	.	.	.	31·8	.	33·6	.
9	.	.	.	31·8	.	32·9	.
10	.	.	.	30·9	.	32·9	.
11	.	.	.	.	.	32·7	.
Midnight	.	.	.	31·2	.	32·4	.

Atmospheric moisture at Jackson Butte, 1879.

[Wet bulb thermometer with Fahrenheit scale.]

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
	°	°	°	°	°	°	°
6 a. m.	56·0	56·2	52·7	54·1	57·2	56·2	54·0
7	58·0	61·8	55·0	56·4	57·4	57·0	58·1
8	57·8	57·3	55·8	57·8	61·0	58·8	59·6
9	58·0	57·7	56·4	58·2	61·2	59·0	59·9
10	59·0	60·5	58·0	59·8	61·2	60·8	60·7
11	60·8	60·4	58·6	60·4	61·5	59·2	60·9
Noon	61·7	59·5	57·4	60·4	61·9	61·0	62·1
1 p. m.	62·6	59·9	58·3	62·0	63·2	61·3	62·3
2	63·5	60·9	57·8	62·9	62·3	61·4	63·2
3	63·4	60·2	58·9	62·6	63·8	61·3	64·1
4	63·8	60·3	59·2	62·8	63·6	61·2	64·0
5	62·0	62·0	58·5	63·0	62·9	61·0	63·3
6	59·8	59·0	57·2	62·2	60·9	60·0	63·2
7	.	.	54·2	.	.	.	.
8	.	.	55·8	.	.	.	.
9	.	.	54·2	.	.	.	.
10	.	.	55·8	.	.	.	.
11	.	.	55·9	.	.	.	.
Midnight	.	.	.	.	.	.	.

Atmospheric moisture at Jackson Butte, 1879—Completed.

[Wet bulb thermometer with Fahrenheit scale.]

Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.
	°	°	°	°	°	°	°
1 a. m.	.	.	.	.	53·0	.	48·3
2	.	.	.	.	53·9	.	48·0
3	.	.	.	.	55·6	.	48·0
4	.	.	.	.	52·0	.	48·7
5	.	.	.	.	53·4	.	47·0
6	58·0	56·9	54·5	.	53·8	55·0	48·2
7	60·5	59·0	56·2	.	54·9	55·0	48·8
8	64·0	60·2	58·2	56·0	56·8	56·1	49·2
9	63·0	63·7	61·9	56·0	59·5	56·5	50·5
10	63·2	64·1	63·0	57·9	59·0	58·0	52·4
11	64·5	63·3	63·0	60·0	59·0	58·9	54·0
Noon	64·0	66·0	63·2	61·0	60·0	60·5	54·6
1 p. m.	54·8	66·2	65·7	61·8	60·9	60·6	55·5
2	.	65·9	65·1	62·8	61·2	61·0	55·3
3	.	66·0	65·2	62·0	62·0	61·1	52·0
4	.	66·1	65·3	62·8	60·8	60·0	49·0
5	.	66·0	64·8	61·5	61·2	57·8	.

Atmospheric moisture at Jackson Butte, 1879—Completed.

[Wet bulb thermometer with Farenheit scale.]

Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.
	°	°	°	°	°	°	°
6	.	62·9	62·4	57·8	.	54·6	.
7	.	.	.	57·0	.	54·0	.
8	.	.	.	58·0	.	51·0	.
9	.	.	.	57·3	.	52·8	.
10	.	.	.	56·5	.	54·1	.
11	.	.	.	55·0	.	53·8	.
Midnight	.	.	.	54·8	.	51·3	.

Round Top, 1879, direction and force of the wind and state of the sky.

[Abbreviations used: Wind, 0 = calm, 1 = very light, 2 = moderate, 3 = fresh, 4 = strong, 5 = very strong, 6 = gale. Sky, c. = clear sky, clds. = clouds, cldy. = cloudy, cov. $\frac{1}{8}$ = one-eighth of sky covered by clouds, sm. = smoky, *sm.* = very smoky, ov. = overcast, *h.* = very hazy, f. = fog.]

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
6 a. m.	SSW. 2 c.	SW. 2 cov. $\frac{1}{8}$	.	.	0 c., sm.	0 c., sm.	SE. 1 c., sm.
7	.	.	.	.	"	"	.
8	.	.	.	SE. 1 c.	.	"	SSE. 1 c., sm.
9	.	.	.	"	SE. 1 c.	SSW. 1 c., sm.	"
10	S. 1 few clds.	.	.	S. 1 c.	SSE. 1 c.	.	.
11	.	WSW. 4	.	"	SE. 1 c.	.	.
Noon	.	WSW. 4 c.	.	SSW. 2 c.	SE. 1	.	.
1 p. m.	SSW. 2 few clds.	.	0 c.	"	.	.	.
2	SSW. 2 cov. $\frac{1}{8}$	SW. 4	.	SW. 2 c., sm.	.	.	.
3	.	"	.	*sm.*	.	.	.
4	.	.	.	.	.	.	.
5	SSW. 4 cov. $\frac{1}{8}$	.	.	sm.	.	.	.
6	"	.	.	.	.	.	
7	.	.	NE. by E. 1 c.	.	.	.	
8	.	SW. 6	E. 1	.	.	.	

Round Top, 1879, direction and force of the wind and state of the sky—Completed.

[Abbreviations used: Wind, 0 = calm, 1 = very light, 2 = moderate, 3 = fresh, 4 = strong, 5 = very strong, 6 = gale. Sky, c. = clear sky, clds. = clouds, cldy. = cloudy, cov. $\frac{1}{8}$ = one-eighth of sky covered by clouds, sm. = smoky, *sm.* = very smoky, ov. = overcast, *h.* = very hazy, f. = fog.]

Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.
1 a. m.	.	*sm.*	.	.	.	.	.
2	.	"	.	.	.	.	.
3	.	"	.	.	.	.	SW. 4
4	.	"	.	.	.	.	.
5	.	"	.	.	.	.	.
6	ESE. 1 c., sm.	SE. 1 c., sm.	NW. 2 c., sm.	.	.	.	.
7	"	"	NW. 1 c., sm.	.	.	.	.
8	SE. 1 c., sm.	SSE. 1 c., sm.	"	.	.	.	.
9	ESE. 1 c., sm.	"	W. 1 c., sm.	SSW. 2 c., sm.	.	SW. 4 clds., sm.	.
10	SSE. 1 c., sm.	.	S. 1 c., sm.	.	.		.
11	.	SSE. 1 few clds., sm.	SSW. 1	.	.		.
Noon	SSE. 1	"	S. 1 c., sm.	SSE. 2 c., sm.	.	SSW. 4 cov. $\frac{1}{8}$, sm.	.
1 p. m.	Dense smoke during afternoon	E. 1 cov. $\frac{1}{4}$, sm.	W. 1 c., sm.	"	.	SSW. 4 cov. $\frac{1}{4}$, sm.	.
2		NW. 1 ov., sm.	NW. 1	"	.	"	SW. 4 cldy.
3		W. 1 cov. $\frac{1}{4}$, *sm.*	NW. 2	SSE. 2 c., *sm.*	.	"	SW. 6 cldy.
4		"	NW. 1	SW. 2 c., sm.	.	*sm.*	clds. cover mountain.
5		"	NW. 2	"	.	.	.
6		WNW. 1 cov. $\frac{1}{8}$, *sm.*	"	"	.	SSW. 4 *sm.*	.
7		.	.	"	.	SSW. 6	.
8		.	.	"	.	"	.
9		.	.	"	.	SW. 6	.
10		.	.	"	.	SW. 5 c., sm.	.
11		.	.	.	.	"	.
Midnight	.	.	.	.	.	.	.

Jackson Butte, 1879, direction and force of the wind and state of the sky.

[Abbreviations used: Wind, o = calm, 1 = very light, 2 = moderate, 3 = fresh, 4 = strong, 5 = very strong, 6 = gale. Sky. c. = clear sky, clds. = clouds, cldy. = cloudy, cov. ⅛ = one-eighth of sky covered by clouds, sm. = smoky, *sm.* = very smoky, ov. = overcast, *h.* = very hazy, f. = fog.]

Hour.	Sept. 8.	Sept. 9.	Sept. 10.	Sept. 11.	Sept. 12.	Sept. 13.	Sept. 14.
6 a. m.	o cov. ⅛, sm.	SE. 1 cov. $\frac{1}{12}$, sm.	NE. 1 sm.	SE. 1 *h.*	SE. 1 *sm.*	o cov. ⅛, *sm.*	o *sm.*
7	o	"	E. 1	o	SE. 1	o	"
8	o	S. 1 few clds.	.	"	"	"	"
9	SW. 1	SW. 1	.	SW. 1	o	"	.
10	SW. 1 cov. $\frac{1}{16}$	SW. 2	.	"	SW. 1	SW. 1	.
11	SW. 2	"	SW. 1	"	"	"	.
Noon	"	"	.	"	SW. 2	"	SW. 1 *sm.*
1 p. m.	.	"	SW. 2	SW. 2	"	SW. 2	"
2	.	"	"	"	W. 2	"	"
3	.	"	SW. 1	"	"	"	"
4	SW. 2 few clds.	"	SW. 1 sm.	SW. 1	"	"	"
5	.	SW. 1	SW. 1 few clds.	"	"	"	"
6	SW. 2 cov. $\frac{1}{12}$	SW. 1 few clds.	o	o few clds.	o	o sm.	o *sm.*
7	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.
11	.	.	N. 1	.	.	.	.
Midnight	.	.	.	.	.	.	.

Jackson Butte, 1879, direction and force of the wind and state of the sky—Continued.

[Abbreviations used: Wind, 0 = calm, 1 = very light, 2 = moderate, 3 = fresh, 4 = strong, 5 = very strong, 6 = gale. Sky. c. = clear sky, clds. = clouds, cldy, = cloudy, cov. $\frac{1}{8}$ = one-eighth of sky covered by clouds, sm. = smoky, $\underline{sm}$. = very smoky, ov. = overcast, $\underline{h}$. = very hazy, f. = fog.]

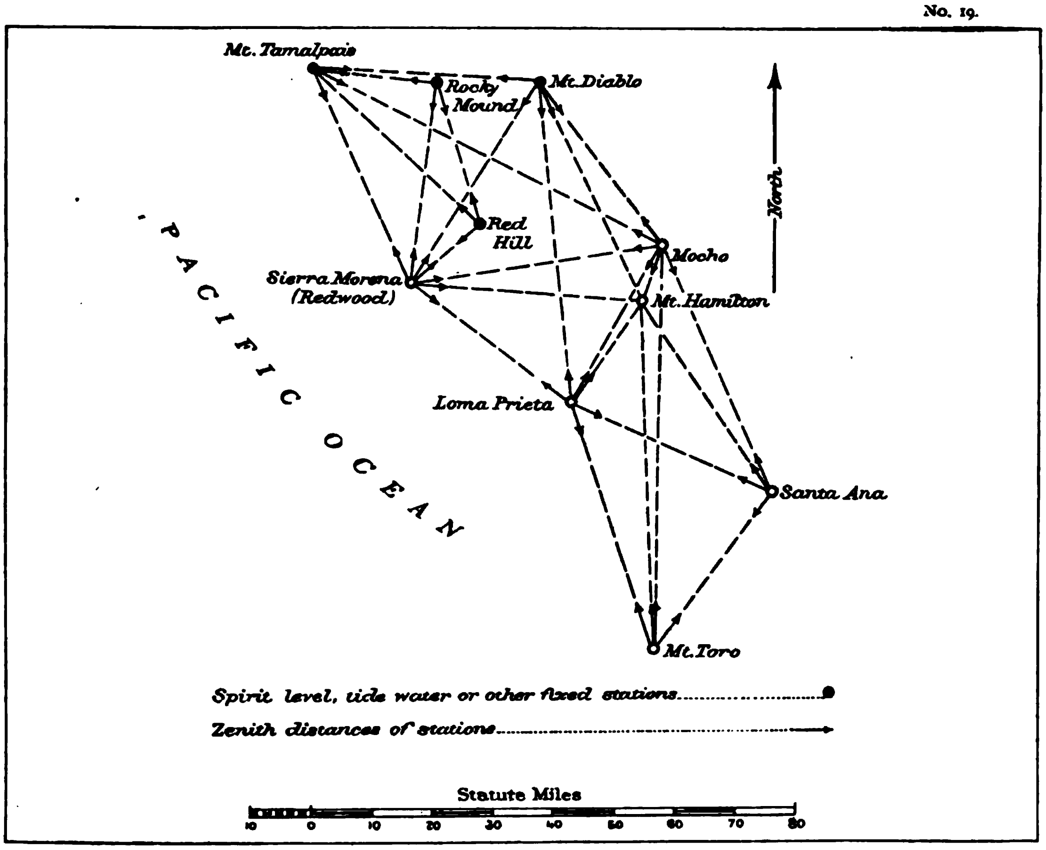
Hour.	Sept. 15.	Sept. 16.	Sept. 17.	Oct. 2.	Oct. 3.	Oct. 4.	Oct. 5.
1 a. m.	.	.	.	.	SE. 1 c.	.	W. 1
2	.	.	.	.	0 c.	.	SW. 2
3	.	.	.		"	.	SW. 1 clds.
4	.	.	.	.	SE. 1 c.	.	SW. 1
5	.	.	.	.	"	.	SW. 1 clds.
6	NE. 1	NE. 2. few clds., $\underline{sm}$.	E. 2 $\underline{sm}$.	SW. 1 c.	SW. 1 c.	SW. 1 few clds.	SW. 1 cov. $\frac{1}{8}$.
7	.	NE. 1	E. 1	"	"	"	SW. 1 f. clds.
8	0	SE. 1	"	"	"	SW. 2 few clds.	SW. 1 cov. $\frac{1}{3}$.
9	.	0	0	"	0 c.	SW. 3 clds.	SW. 1 cov. $\frac{7}{8}$.
10	SW. 1	"	SW. 1	"	SW. 1 c.	"	clds.
11	"	SW. 1	"	"	"	"	SW. 1 clds.
Noon	SW. 2 few clds.	"	SW. 2	SW. 2 c.	"	"	SW. 2 clds.
1 p. m.	SW. 2 $\underline{sm}$.	"	SW. 1	SW. 1 c.	"	"	SW. 1 clds.
2	Smoke during after-noon.	SW. 1 few clds.	"	"	"	"	SW. 2 clds.
3		"	"	"	"	SW. 2 clds.	SW. 3 clds.
4		SW. 1	"	"	"	"	SW. 3 cld capped.
5		SW. 1 few clds.	"	"	0 c.	SW. 1 clds.	.
6	.	0	0	"	.	"	.
7	.	.	.	"	.	N. 1 clds.	.
8	.	.	.	.	.	N. 1	
9	.	.	.	0 c.	.	0	.
10	.	.	.	"	.	0 clds.	.
11	.	.	.	SE. 1 c.	.	.	.
Midnight	.		.	"	.	.	.

E. DETERMINATION OF HEIGHTS OF PACIFIC COAST STATIONS SOUTH OF LATITUDE 38° AND SURROUNDING MOUNT HAMILTON, CALIFORNIA.

1. INTRODUCTION.

In view of the fact that Mount Hamilton (Lick Observatory) is one of the stations connected with the longitudes of the arc of the parallel, the data and adjustment of heights of the stations surrounding the mountain demand to be presented here. The

No. 19.



accompanying diagram shows the observations: advantage is taken of the fact that station Red Hill has been connected with tide water,* making its elevation above the half-tide level 57·12 metres (187·40 feet). It is also expected that a somewhat improved value for the height of Mocho may result.

* By Assistant R. D. Cutts, in 1852.

2. ABSTRACT OF REDUCED ZENITH DISTANCES.

Mount Diablo. August and September, 1876. Vertical Circle, No. 37. W. Eimbeck, observer. November and December, 1884. Vertical Circle, No. 80. F. Morse, observer. July, 1892. Vertical Circle, No. 111. F. W. Edmonds, observer. George Davidson, chief of party in 1876–84–92.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ.	P.	T. (cent.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
6	Mocho, 1876	90 07 54·3	+ 4·7	−0·7	90 07 58·3	661	17·7	
12	Mocho, 1884	90 07 26·4	+10·7	−0·7	90 07 36·4	654	11·0	
9	Mocho, 1892	90 07 52·9	− 5·6	0·0	90 07 58·5	663*	21·5	
27	Mocho, mean				90 07 48·6			4·739 49
4	Loma Prieta, 1876	90 20 18·8	+ 3·0	−0·1	90 20 21·7	661	18·9	
11	Loma Prieta, 1884	90 19 39·0	+ 8·7	−0·1	90 19 47·6	654	13·4	
15	Loma Prieta, mean				90 19 56·7			4·933 29
11	Sierra Morena, 1884	90 37 32·1	+10·0	−0·1	90 37 42·0	654	12·8	4·798 25
1	Mount Conness, 1892	90 12 30·6	+ 1·1	0·0	90 12 31·7	664*	19·9	5·358 24
11	Mount Hamilton, top of small dome, 1884	90 07 42·3	+ 4·6	−0·6	90 07 46·3	....	....	
3	Mount Hamilton, top of small dome, 1892	90 07 42·2	+ 0·8	0·0	90 07 43·0	....	....	
14	Mount Hamilton, top of small dome, mean				90 07 45·6			4·809 84

Observations in 1876 mostly between 5 hours 15 minutes and 8 hours a. m., and between 3 hours 20 minutes and 7 hours p. m.; in 1884 between 10 hours a. m. and 1 hour p. m; in 1892 between noon and 1 hour p. m.

Mocho. September and October, 1887. Vertical Circle, No. 57. P. A. Welker, observer; George Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
8	Mount Hamilton, top of small dome	89 51 46·1	+106·5	−3·4	89 53 29·2	....	....	
		89 53 27·5	−14·3	0·0	89 53 13·2	....	....	
	Mean				89 53 21·2			4·227 98
10	Mount Diablo	90 17 04·3	+ 1·0	+0·1	90 17 05·4	657	24·4	4·739 49
6	Mount Tamalpais	90 38 21·1	+ 0·9	+0·1	90 38 22·1	656	21·5	5·018 32
12	Loma Prieta	90 17 32·3	+ 5·1	0·0	90 17 37·4	657	24·4	4·681 43
13	Santa Ana	90 23 19·9	+ 3·3	0·0	90 23 23·2	657	24·3	4·843 05
11	Sierra Morena	90 41 17·9	+ 1·9	0·0	90 41 19·8	657	25·0	4·826 15
4	Round Top*	90 09 06·1	+ 0·1	−0·1	90 09 06·1	654	26·0	5·277 86
8	Mount Conness	90 03 44·2	− 0·5	−0·2	90 03 43·5	656	21·7	5·310 41

Observations taken between 11 hours 15 minutes a. m. and 1 hour 20 minutes p. m.

Mount Tamalpais. March, 1859. Vertical Circle, No. 80. George Davidson, observer. September and October, 1882. Vertical Circle, No. 111. E. F. Dickins, and J. F. Pratt, observers. G. Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
11	Sierra Morena, 1882	90 17 01·9	+ 2·5	−0·2	90 17 04·2	694	21·9	4·795 34
7	Mocho, 1882	90 08 43·6	+ 0·4	−0·1	90 08 43·9	694	19·5	5·018 32
4	Rocky Mound, 1882	90 46 14·4	+ 0·4	0·0	90 46 14·8	....	....	
2	Rocky Mound, 1859	90 46 03·3	+18·8	0·0	90 46 22·1	....	....	
6	Rocky Mound, mean				90 46 17·2			4·498 10

Observations in 1859 between 2 hours 45 minutes and 4 hours 45 minutes p. m.; in 1882 between noon and 4 hours 30 minutes p. m.

* Result doubtful.

Sierra Morena (Redwood). December, 1883, and January, 1884. Vertical Circle, No. 111. R. A. Marr, observer; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ	*P.*	*T.* (cent.)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
11	Mount Tamalpais	90 10 46·1	+ 0·5	+0·1	90 10 46·7	704	13·9	4·795 34
12	Mount Diablo	89 49 51·0	− 0·1	+0·5	89 49 51·4	703	14·5	4·798 25
12	Loma Prieta	89 44 29·0	+ 3·4	+0·1	89 44 32·5	703	13·6	4·723 55
13	Mocho	89 48 32·2	+ 0·2	+0·5	89 48 32·9	704	12·7	4·826 15
8	Mount Hamilton, top of small dome	89 40 55·8	− 4·7	+0·5	89 40 51·6	....	....	4·774 12
11	Red Hill	91 40 44·2	− 2·5	−3·0	91 40 38·7	....	....	4·388 69
6½	Rocky Mound	90 31 26·7	− 2·0	0·0	90 31 24·7	....	....	4·721 83

Observations between 11 hours 58 minutes a. m. and 1 hour 14 minutes p. m.

Loma Prieta (Mount Bache). February and March, 1884. Vertical Circle, No. 111. R. A. Marr, observer; George Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	*mm.*	°	
10½	Mount Diablo	90 18 54·2	− 1·7	−0·2	90 18 52·3	669	16·0	4·933 29
10	Sierra Morena	90 39 11·5	− 1·6	0·0	90 39 09·9	668	16·4	4·723 55
10	Mocho	90 04 40·6	− 3·5	−0·4	90 04 36·7	669	15·8	4·681 43
9½	Mount Toro	90 19 18·9	− 1·0	+0·2	90 19 18·1	....	....	4·833 86
11	Santa Ana	90 16 29·8	+ 0·3	−0·2	90 16 29·9	....	....	4·770 63
5	Mount Hamilton, top of small dome	89 52 08·4	−13·4	−0·7	89 51 54·3	....	....	4·494 46

Observations between 11 hours 50 minutes a. m. and 1 hour 4 minutes p. m.

Mount Toro. January and February, 1885. Vertical Circle, No. 80. R. A. Marr and F. Morse, observers; George Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	*mm.*	°	
12	Loma Prieta	90 11 38·1	+ 1·1	+0·3	90 11 39·5	....	....	4·833 86
11	Santa Ana	90 10 44·4	+ 0·8	0·0	90 10 45·2	....	....	4·731 16
5	Mocho	90 18 06·6	− 0·9	+0·2	90 18 05·9	....	....	5·024 03
9	Mount Hamilton, top of small dome	90 12 17·7	− 4·3	+0·2	90 12 13·6	....	....	4·957 02

Observations between noon and 1 hour p. m.

Santa Ana. November and December, 1885. Vertical Circle, No. 80. E. F. Dickins and F. Morse, observers; G. Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	*mm.*	°	
11	Loma Prieta	90 10 11·1	+ 2·1	+0·1	90 10 13·3	..	..	4·770 63
11	Mount Toro	90 13 17·5	+ 0·3	−0·2	90 13 17·6	..	..	4·731 16
11	Mocho	90 08 36·8	− 1·7	+0·2	90 08 35·3	..	..	4·843 05
6	Mount Hamilton, top of small dome	90 02 41·9	− 5·4	+0·2	90 02 36·7	..	..	4·782 49

Observations between 11 hours 50 minutes a. m. and 1 hour 5 minutes p. m.

Rocky Mound. June, 1885. Vertical Circle, No. 80. F. Morse, observer; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ	P.	T. (cent.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
4	Mount Tamalpais	89 27 33·2	− 2·6	0·0	89 27 30·6	..	..	4·498 10
4	Red Hill	90 41 36·0	− 3·2	0·0	90 41 32·8	..	..	4·590 91
1	Sierra Morena	89 51 23·7	− 1·2	0·0	89 51 22·5	..	..	4·721 83

Observations between noon and 1 hour p. m.

Red Hill. June, 1885. Vertical Circle, No. 80. F. Morse, observer; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of station.	Reduction for eccentricity.	Reduced ζ	P.	T. (cent.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
3	Sierra Morena	88 29 45·4	− 2·4	0·0	88 29 43·0	..	..	4·388 69
2	Rocky Mound	89 36 08·9	− 2·6	0·0	89 36 06·3	..	..	4·590 91
2	Mount Tamalpais	89 31 27·0	− 1·3	0·0	89 31 25·7	..	..	4·782 06

3. COEFFICIENT OF REFRACTION.

The coefficient of refraction and its weight for each line where there were reciprocal zenith distances were computed by the usual formulæ—

$$m = 0{\cdot}5 - \frac{\rho \sin 1''}{2s}(\zeta_{\prime} + \zeta_{\prime\prime} - 180°) \text{ and } p = \frac{n_{\prime} n_{\prime\prime}}{n_{\prime} + n_{\prime\prime}} \cdot \frac{s^2}{10^{10}}$$

with the following results—

Stations.	m.	p.
Mount Diablo to Mount Tamalpais	0·077	1·85
Mocho to Mount Diablo	·080	2·20
Mocho to Mount Tamalpais	·081	3·52
Mount Diablo to Sierra Morena	·094	2·26
Mount Tamalpais to Sierra Morena	·087	2·15
Mocho to Sierra Morena	·086	2·67
Mount Diablo to Loma Prieta	·081	4·55
Mount Tamalpais to Rocky Mound	·093	0·24
Sierra Morena to Rocky Mound	·100	0·24
Sierra Morena to Red Hill	·107	0·14
Rocky Mound to Red Hill	·081	0·20
Loma Prieta to Sierra Morena	·085	1·53
Mocho to Loma Prieta	·071	1·26
Mocho to Santa Ana	·075	2·89
Loma Prieta to Santa Ana	·079	1·91
Loma Prieta to Mount Toro	·080	2·47
Santa Ana to Mount Toro	·086	1·60
Weighted mean	0·082	

This mean value was used in computing the difference of height of two stations when the zenith distance was observed at only one of them.

4. COMPUTATION AND ADJUSTMENT OF DIFFERENCES OF HEIGHT.

The difference of height of two stations at which the reciprocal zenith distances $\zeta_{\text{I}}\ \zeta_{\text{II}}$ were observed and its weight were computed as usual by the formulae—

$$\Delta h = h_{\text{II}} - h_{\text{I}} = s \tan \tfrac{1}{2}(\zeta_{\text{II}} - \zeta_{\text{I}})\left[1 + \frac{h_{\text{I}} + h_{\text{II}}}{2\rho} + \frac{s^2}{12\rho^2} + \ldots\ldots \right] \text{ and } p = \frac{n_{\text{I}} n_{\text{II}}}{n_{\text{I}} + n_{\text{II}}} \cdot \frac{10^{10}}{s^2}$$

Where only one zenith distance was observed, a value for the coefficient of refraction was assumed and the formulae—

$$\Delta h = s \cot \zeta + \frac{1 - 2m}{2\rho} s^2 - \frac{1 - m}{\rho} s^2 \cot \zeta + \ldots\ldots \text{ and } p = \frac{n}{4} \cdot \frac{10^{10}}{s^2}$$

were used. In the following table of differences of height the first 16 results are from reciprocal zenith distances, the others from one zenith distance only.

The method of "direct observations" was used in adjusting the differences of height. As may be seen from the sketch, ten stations are involved, of which the heights of three are fixed—Mount Diablo and Mount Tamalpais by the previous adjustment and Red Hill from spirit leveling by Assistant R. D. Cutts in 1852. The heights of these three stations and the assumed approximate heights of the seven others are as follows:

	m.		*m.*
Mount Diablo	1 173·10	Loma Prieta	1 157 $+x_4$
Mount Tamalpais	790·74	Santa Ana	1 101 $+x_5$
Red Hill	57·12	Mount Toro	1 081 $+x_6$
Sierra Morena	736 $+x_1$	Mount Hamilton (top of small dome)	1 299 $+x_7$
Mocho	1 248 $+x_2$		
Rocky Mound	429 $+x_3$		

Differences of height and resulting observation equations.

Stations.	Δh.	p.	Observation equation.	Adjusted Δh.	Discrepancy.
	m.			*m.*	*m.*
Mocho to Mount Diablo	74·10	24·2	$0=+\ 0·80+x_2$	74·98	0·88
Mocho to Mount Tamalpais	449·71	3·0	$0=+\ 7·55+x_2$	457·34	7·63
Mount Diablo to Sierra Morena	437·36	14·6	$0=+\ 0·26+x_1$	437·17	0·19
Mount Tamalpais to Sierra Morena	57·13	14·1	$0=+\ 2·39+x_1$	54·81	2·32
Mocho to Sierra Morena	514·52	13·3	$0=+\ 2·52+x_1-x_2$	512·15	2·37
Mount Diablo to Loma Prieta	13·39	8·4	$0=+\ 2·71-x_4$	15·64	2·25
Mount Tamalpais to Rocky Mound	360·79	24·2	$0=+\ 0·95-x_3$	361·29	0·50
Sierra Morena to Rocky Mound	306·92	3·1	$0=+\ 0·08+x_1-x_3$	306·48	0·44
Sierra Morena to Red Hill	679·83	39·4	$0=+\ 0·95-x_1$	678·81	1·02
Rocky Mound to Red Hill	371·11	8·8	$0=+\ 0·77+x_3$	372·33	1·22
Loma Prieta to Sierra Morena	420·43	19·5	$0=+\ 0·57-x_1+x_4$	421·53	1·10
Mocho to Loma Prieta	90·90	23·7	$0=+\ 0·10+x_2-x_4$	90·62	0·28
Mocho to Santa Ana	149·98	12·3	$0=+\ 2·98-x_2+x_5$	146·72	3·26
Loma Prieta to Santa Ana	53·84	15·8	$0=+\ 2·16+x_4-x_5$	56·10	2·26
Loma Prieta to Mount Toro	75·84	11·4	$0=+\ 0·16+x_4-x_6$	76·30	0·46

Differences of height and resulting observation equations--Completed.

Stations.	Δh.	p.	Observation equation.	Adjusted Δh.	Discrepancy.
	m.			*m.*	*m.*
Santa Ana to Mount Toro	19·90	19·0	$0=+0·10+x_5-x_6$	20·20	0·30
Mount Tamalpais to Red Hill	743·61	1·4	....	733·62	(9·99)
Mocho to Mount Toro	177·96	1·1	$0=+10·96-x_2+x_6$	166·92	11·04
Mount Hamilton to Mount Diablo	127·98	8·4	$0=+2·08-x_7$	125·77	2·21
Mount Hamilton to Mocho	51·45	70·0	$0=+0·45+x_2-x_7$	50·79	0·66
Mount Hamilton to Sierra Morena	562·31	5·7	$0=+0·69-x_1+x_7$	562·94	0·63
Mount Hamilton to Loma Prieta	137·51	12·8	$0=+4·49-x_4+x_7$	141·41	3·90
Mount Hamilton to Mount Toro	217·21	2·7	$0=+0·79-x_6+x_7$	217·71	0·50
Mount Hamilton to Santa Ana	195·03	4·1	$0=+2·97-x_5+x_7$	197·51	2·48

The solution of the normal equations formed from the above observation equations gave the following corrections to the assumed heights:

$x_1=-·07$ $\quad x_5=+·36$
$x_2=-·08$ $\quad x_6=+·16$
$x_3=-·45$ $\quad x_7=-·13$
$x_4=+·46$

hence the resulting heights—

	Metres.	*Feet.*		*Metres.*	*Feet.*
Sierra Morena	735·9 or	2 414	Santa Ana	1 101·4 or	3 614
Mocho	1 248·1	4 095	Mount Toro	1 081·2	3 547
Rocky Mound	429·4	1 409	Mount Hamilton, top of small dome	1 298·9	4 261
Loma Prieta	1 157·5	3 798			

In a letter from Director Holden the height of top of the small dome above the marble floor of the Lick Observatory is stated to be 40 feet 4 inches (12·3 metres); hence the height of the marble floor is 1 286·6 metres, or 4 221 feet.

In the table of differences of height, the last two columns contain the adjusted values and the differences between them and the values resulting directly from the observations.

F. DETERMINATION OF HEIGHTS OF STATIONS OF PRIMARY TRIANGULATION ACROSS THE SACRAMENTO AND SAN JOAQUIN VALLEYS, CALIFORNIA.

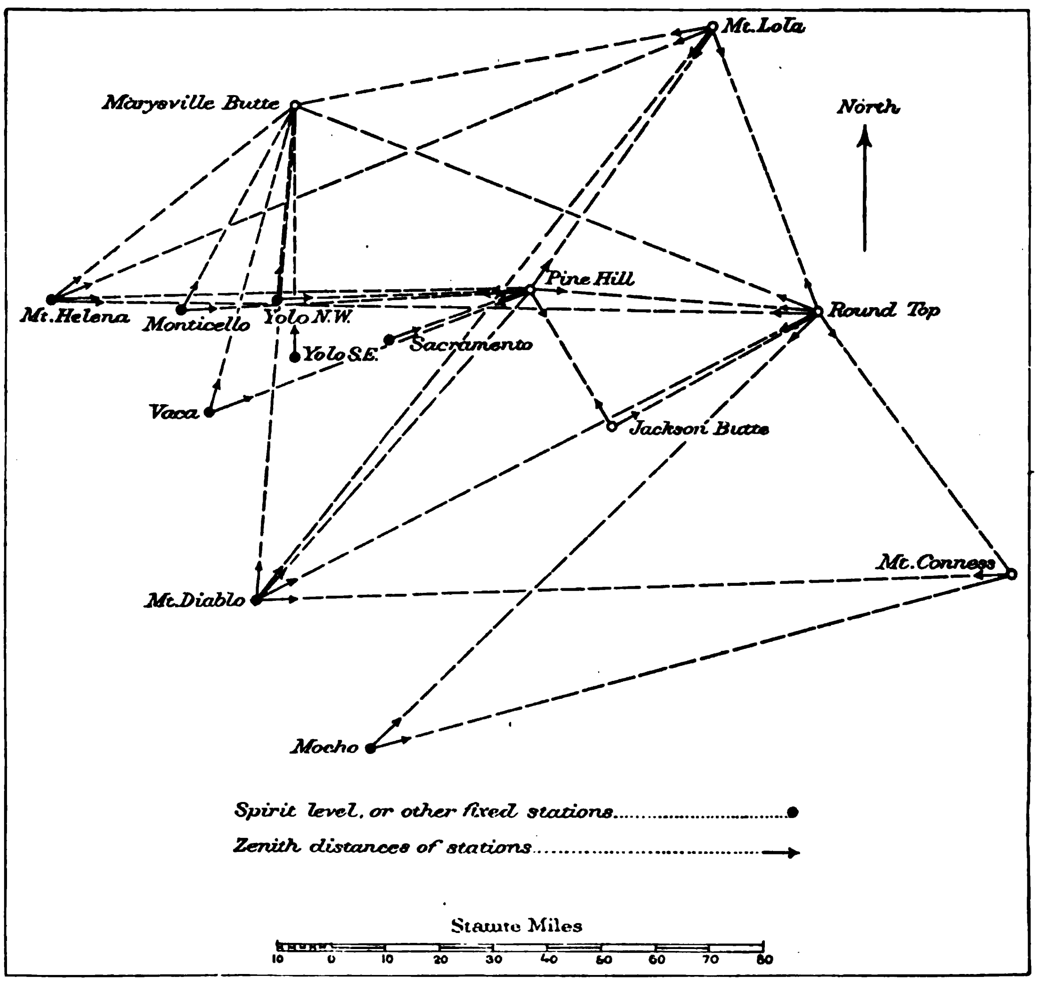
I. INTRODUCTION.

The difficulty experienced when attempting the determination of heights on the crest of the Sierra Nevada by means of zenith distances measured over the long lines spanning the great valley of California rendered it necessary to supplement the older measures. This was done in the summer of 1898, by strictly simultaneous reciprocal measures over shorter lines, along which the variations of refraction are less injurious.

It was noted that the nearer the terminal stations of a line approached the ocean

the greater was the refraction, and that in the diurnal variation the hour of the minimum refraction occurred in the forenoon for coast stations, but in the early afternoon for stations in the interior. Apparently, also, a great difference in the angle of refraction was shown to subsist at the lower and upper stations in the Martinez East and Mount Diablo experiments, where the combination with spirit leveling enabled us to determine this difference, subject, however, to any effect of the local deflection of the verticals of the stations in the plane of the measures.

No. [illegible].



If, further, we reflect that the resulting zenith distances, as tabulated, were taken mostly at different hours of the day, in different months of the year, and in different years, with only the new (1898) measures simultaneous, it does not seem surprising that it became necessary to exclude the resulting differences of height over the several *long* lines across the valley which range up to 229 kilometres or 142 statute miles. Comparing results over these long lines from the above compiled reciprocal measures, with results derived from observations at one end of a line only, the relative weights of

the latter are not so much inferior as would appear at first sight; due weights were given as shown farther on. The effect on the value of the difference of height from local deflections of the verticals is, in general, within the uncertainty of the measures of zenith distances, which can hardly be depended upon within about 10 seconds, while the local deflections do not ordinarily reach half this amount. Neither local deflections, so far as known, nor the effect of an omitted term in the formula for computing heights, involving the difference of refraction at the upper and lower station, as far as this could be ascertained, could be made to produce any closer results.

The process of reduction actually followed is as follows: With reference to accompanying sketch of the lines and measures involved, the height of the central station, Pine Hill, was first determined. There are 6 lines to it from stations of fixed height, of which the two long and one-sided lines from Mount Helena and Mount Diablo were excluded, and less weight was given for the one-sided line from Yolo Base Northwest. The weighted mean of the 4 determinations was adopted. Similarly the weighted results from the 8 lines to Marysville Butte (omitting the two long ones) were combined. The average value of the coefficient of refraction for the locality was used; then followed the ascent to Jackson Butte, Round Top and Mount Lola, where a check was had from spirit levels of the railroad to Truckee and thence to Mount Lola. The difference in height between the valley stations Pine Hill and Jackson Butte and the mountain stations Round Top and Mount Lola is so great (over 2000 metres), that it became necessary to retain in the formula for computing the difference of height the term depending on the different values of the refraction at the upper and lower stations.

2. ABSTRACT OF REDUCED ZENITH DISTANCES.

Southeast Yolo Base. August, 1880. Vertical Circle, No. 80. E. F. Dickins, observer; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity	Reduced ζ.	P.	T. (Cen.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
6	Marysville Butte	89 49 20.4	−4.0	−0.8	89 49 15.6	751	32.4	4.876 60

Observations mostly between 2 hours 30 minutes and 5 hours 30 minutes p. m.

Northwest Yolo Base. August and September, 1880. Vertical Circle, No. 80. J. J. Gilbert, observer; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity	Reduced ζ.	P.	T. (Cen.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
8	Pine Hill	89 51 11.8	−0.8	+0.1	89 51 11.1	754	32.7	4.878 89
11	Marysville Butte	89 38 29.2	−0.8	−0.2	89 38 28.2	753	33.6	4.767 95

Observations mostly between 2 hours and 5 hours 30 minutes p. m.

Monticello. October, 1880. Vertical Circle, No. 80. E. F. Dickins, observer; George Davidson, chief of party. June, 1898. Vertical Circle, No. 80. F. Morse, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity	Reduced ζ.	P.	T. (Cen.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
8	Marysville Butte, 1880	90 30 11.4	+0.2	0.0	90 30 11.6	682	18.3	4.833 70
7	Pine Hill, 1880	90 33 37.4	0.0	+0.1	90 33 37.5	682	18.1	Not used
7	Pine Hill, 1898	90 34 17.5	−2.0	0.0	90 34 15.5	682	22.1	5.019 41

Observations in 1880 mostly between 2 hours and 5 hours 30 minutes p. m.; in 1898 between 10 hours 30 minutes a. m. and 4 hours 30 minutes p. m.

Vaca. November, 1880. Vertical Circle, No. 80. E. F. Dickins, observer; George Davidson, chief of party. June, 1898. Vertical Circle, No. 80. F. Morse, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T. (Cent.)	Log. s.
		° ′ ″	″	″	° ′ ″	mm.	°	
8	Marysville Butte, 1880	90 25 03·6	+0·3	−0·2	90 25 03·7	701	14·4	4·977 57
5	Pine Hill, 1880	90 26 30·5	+0·1	−0·1	90 26 30·5	700	16·0	Not used
6	Pine Hill, 1898	90 27 05·6	−2·0	0·0	90 27 03·6	699	24·8	5·011 71

Observations in 1880 between 1 hour and 4 hours 30 minutes p.m.; in 1898 between 10 hours 30 minutes a.m. and 4 hours 30 minutes p.m.

Mount Diablo. August and September, 1876. Vertical Circle, No. 37. W. Eimbeck, observer; George Davidson, chief of party. July, 1892. Vertical Circle, No. 111. F. W. Edmonds, observer; George Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
8	Round Top, 1876	90 06 57·4	+2·9	−1·1	90 06 59·2	662	17·3	5·275 46
6	Marysville Butte, 1876	90 45 37·8	+3·6	0·0	90 45 41·4	662	16·1	5·167 94
6	Mount Lola, 1876	90 25 07·6	+2·3	−0·6	90 25 09·3	661	16·2	5·339 86
3	Pine Hill, 1876	90 43 25·1	+4·4	−0·3	90 43 29·2	662	15·7	5·090 55
1	Mount Conness, 1892	90 12 30·6	+1·1	0·0	90 12 31·7	664	19·9	5·358 24

Observations in 1876 mostly between 5 hours 15 minutes and 8 hours a.m., and between 3 hours 20 minutes and 7 hours p.m.; in 1892 about 12 hours 15 minutes p.m.

Mocho. September and October, 1887. Vertical Circle, No. 57. P. A. Welker, observer; George Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
4	Round Top	90 09 06·1	+0·1	−0·1	90 09 06·1	654	26·0	5·277 86
8	Mount Conness	90 03 44·2	−0·5	−0·2	90 03 43·5	656	21·7	5·310 41

Observations between 11 hours 30 minutes a.m. and 1 hour 20 minutes p.m.

Mount Helena. October and November, 1876. Vertical Circle, No. 37. W. Eimbeck, observer George Davidson, chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
4	Mount Lola	90 24 27·7	+0·9	+0·3	90 24 28·9	654	11·8	5·330 16
8	Marysville Butte	90 46 14·6	+2·2	0·0	90 46 16·8	652	9·1	4·965 06
9	Round Top	90 23 56·4	+0·9	+0·6	90 23 57·9	652	8·3	5·360 02
6	Pine Hill	90 48 20·8	+1·5	+0·3	90 48 22·6	654	10·8	5·155 48

Observations mostly between 6 hours 40 minutes and 9 hours a.m., and between 3 hours 30 minutes and 5 hours p.m.

Sacramento. May, 1898. Vertical Circle, No. 80. F. Morse, observer and chief of party.

		° ′ ″	″	″	° ′ ″	mm.	°	
9	Pine Hill	89 28 02·9	−171·9	+0·3	89 25 11·3	755	22·8	4·663 23

Observations between 10 hours 30 minutes a.m. and 4 hours and 30 minutes p.m.

Pine Hill. May and June, 1898. Vertical Circle, No. 100. J. J. Gilbert, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T.* (Cent.)	Log. *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
5	Jackson Butte	90 06 01 ·3	− 8 ·3	0 ·0	90 05 53 ·0	706	25 ·8	4 ·683 27
10	Sacramento	90 53 35 ·8	+163 ·3	0 ·0	90 56 19 ·1	705	18 ·8	4 ·668 23
6	Vaca	90 20 16 ·8	− 1 ·9	0 ·0	90 20 14 ·9	706	26 ·8	5 ·011 71
7	Monticello	90 14 10 ·2	− 1 ·9	0 ·0	90 14 08 ·3	707	26 ·6	5 ·019 41
5	Mount Lola	89 05 30 ·8	− 1 ·8	0 ·0	89 05 29 ·0	704	31 ·9	4 ·981 99
17	Round Top	88 39 14 ·2	− 5 ·2	0 ·0	88 39 09 ·0	707	24 ·4	4 ·936 02

Observations between 10 hours 30 minutes a. m. and 4 hours 30 minutes p. m.

Jackson Butte. September and October, 1879. Vertical Circle, No. 111. J. F. Pratt, observer; George Davidson, chief of party. May, 1898. Vertical Circle, No. 80. F. Morse, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T.* (Cent.)	Log. *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
14	Round Top*, 1879				88 20 02 ·6	701	24 ·9	4 ·859 57
7	Pine Hill, 1879	90 16 49 ·4	−1 ·0	0 ·0	90 16 48 ·4	..	...	
4	Pine Hill, 1898	90 16 53 ·9	−5 ·4	0 ·0	90 16 48 ·5	701	25 ·8	
11	Pine Hill, mean				90 16 48 ·4			4 ·683 27

Observations in 1879 on Round Top at all hours; on Pine Hill between 10 hours 17 minutes and 10 hours 26 minutes a. m.; in 1898 between 10 hours 30 minutes a. m. and 4 hours 30 minutes p. m.

Mount Lola. July, 1879. Vertical Circle, No. 80. J. F. Pratt, observer; George Davidson, chief of party. June, 1898. Vertical Circle, No. 80. F. Morse, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T.* (Cent.)	Log. *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
10	Pah Rah, 1879	90 31 24 ·8	−0 ·3	−0 ·2	90 31 24 ·3	547	12 ·6	4 ·936 44
10	Mount Diablo, 1879	91 16 15 ·5	−0 ·4	+0 ·1	91 16 15 ·2	546	8 ·9	5 ·339 86
12	Mount Como, 1879	90 22 53 ·3	−1 ·0	+0 ·5	90 22 52 ·8	546	12 ·5	4 ·951 80
10	Mount Helena, 1879	91 13 19 ·1	−0 ·3	0 ·0	91 13 18 ·8	546	7 ·9	5 ·330 16
9	Marysville Butte, 1879	91 27 44 ·5	−0 ·5	−0 ·1	91 27 43 ·9	546	10 ·2	5 ·107 30
11	Round Top, 1879	90 07 24 ·9	−0 ·6	+0 ·6	90 07 24 ·9	546	12 ·2	4 ·959 22
10	Pine Hill, 1879	91 40 21 ·9	−0 ·5	−0 ·3	91 40 21 ·1	546	12 ·1	
5	Pine Hill, 1898	91 40 37 ·2	−2 ·3	0 ·0	91 40 34 ·9	548	16 ·3	
15	Pine Hill, mean				91 40 25 ·7			4 ·981 99

Observations in 1879 between 5 hours 20 minutes and 9 hours a. m., and between 3 hours and 6 hours 25 minutes p. m.; in 1898 between 10 hours 30 minutes a. m. and 4 hours 30 minutes p. m.

Mount Conness. August and September, 1890. Vertical Circle, No. 80. J. J. Gilbert and I. Winston, observers; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T.* (Cent.)	Log. *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
4	Mount Diablo	91 32 59 ·2	+ 67 ·5	−1 ·2	91 34 05 ·5	...	...	5 ·358 24
7	Mount Grant	90 34 04 ·1	+189 ·1	0 ·0	90 37 13 ·2	...	...	4 ·910 91

Observations between 11 hours 50 minutes a. m. and 12 hours 50 minutes p. m.

*See discussion of special observations for diurnal variation of refraction pp. 280–296.

Round Top. August, September, and October, 1879. Vertical Circle, No. 80. J. J. Gilbert and J. F. Pratt, observers; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduction ζ.	*P.*	*T* (Cen.)	Log *s*.
		° ′ ″	″	″	° ′ ″	*mm.*	°	
19	Mount Lola	90 36 00·8	−0·2	+0·2	90 36 00·8	524	12·1	4·959 22
18	Mount Como	90 38 13·6	−2·3	+0·3	90 38 11·6	526	12·7	4·782 38
19	Mount Grant	90 16 45·7	+0·8	+0·1	90 16 46·6	526	12·7	5·024 71
20	Mount Conness	89 59 36·4	−1·7	−0·1	89 59 34·6	525	12·2	4·989 13
14	Jackson Butte*				92 13 54·8	526	9·1	4·859 57
16	Mount Diablo	91 20 17·6	0·0	0·0	91 20 17·6	523	6·8	5·275 46
7	Mount Helena	91 20 36·6	0·0	0·0	91 20 36·6	521	4·6	5·360 02
18	Pine Hill	92 01 30·8	+0·3	+0·1	92 01 31·2	524	9·2	4·936 02
9	Marysville Butte	91 30 34·1	0·0	0·0	91 30 34·1	522	5·1	5·227 52
16	Mocho	91 19 05·2	+0·2	0·0	91 19 05·4	524	6·8	5·227 86

Observations between 6 hours 20 minutes a. m. and 6 hours 30 minutes p. m.

3. COEFFICIENT OF REFRACTION.

The coefficient of refraction was computed as usual by the formula—

$$m = 0{\cdot}5 - \frac{\rho \sin 1''}{2s}(\zeta_{\text{I}} + \zeta_{\text{II}} - 180^\circ)$$

and its weight by $p = \frac{n_{\text{I}}\, n_{\text{II}}}{n_{\text{I}} + n_{\text{II}}} \cdot \frac{s^2}{10^{10}}$, with the following results:

Stations.	*m.*	*p.*	Stations.	*m.*	*p.*
Mount Helena to Mount Lola	·076	13·1	Pine Hill to Vaca	·072	3.2
Mount Helena to Round Top	·076	20·7	Pine Hill to Jackson Butte	·064	0.8
Mount Diablo to Mount Lola	·070	18·0	Round Top to Pine Hill	·062	6·5
Mount Diablo to Round Top	·070	19·0	Mount Lola to Pine Hill	·057	3·5
Mount Diablo to Mount Conness	·066	4·2	Mount Lola to Round Top	·058	5·8
Pine Hill to Sacramento	·071	1·0	Round Top to Jackson Butte	·057	3·7
Pine Hill to Monticello	·070	3·8			

They are divided into three groups according as they are derived from lines extending across the valley, in the valley or up the slope of the Sierra Nevada. As noted in the preceding discussion of heights, these results show a continuation of the decrease in *m* as we recede from the Pacific coast.

4. DIFFERENCES OF HEIGHT AND THEIR ADJUSTMENT.

The formula used for computing differences of height from reciprocal zenith distances in the preceding parts of this paper is based on the assumption of equal refractions at the two stations. It was recognized that in fact this is not the case even

*See discussion of special observations for diurnal variation of refraction pp. 280–296.

for strictly simultaneous observations, and the change in refraction going from the Pacific coast inland was especially noticeable. It was evident, however, that local conditions had a powerful effect upon the refraction, and it seemed best, as usual, to trust to the adjustment to correct for the assumption of equal refractions where in reality they were unequal. The same plan has been followed here except for the three lines Pine Hill to Mount Lola, Pine Hill to Round Top, and Jackson Butte to Round Top, extending from the valley to the top of the Sierra Nevada. These lines are long and the effect of even a small difference of refraction is quite marked. A fair estimate of the difference may be obtained by comparing the values of m between stations in the valley with those derived from lines in the mountains. For these three lines the formula—

$$\triangle h = h_{\text{I}} - h_{\text{II}} = \left[s \tan \tfrac{1}{2} (\zeta_{\text{I}} - \zeta_{\text{II}}) + \frac{m_{\text{I}} - m_{\text{II}}}{2} \cdot \frac{s^2}{\rho}\right] \left[1 + \frac{h_{\text{I}} + h_{\text{II}}}{2\rho} + \frac{s^2}{12\rho^2} + \ldots\ldots\right]$$

was used, adopting for $(m_{\text{I}} - m_{\text{II}})$ the value $-0{\cdot}005$.

The relative weight was computed from the usual expression $p = \frac{n_{\text{I}} n_{\text{II}}}{n_{\text{I}} + n_{\text{II}}} \cdot \frac{10^{10}}{s^2}$.

Where the zenith distance was observed at only one end of a line, the difference of height was computed from the formula—

$$\Delta h = s \cot \zeta + \frac{1 - 2m}{2\rho} \cdot s^2 + \frac{1 - m}{\rho} s^2 \cot^2 \zeta + \ldots\ldots$$

for which a value for m was assumed, depending in each case on values derived from lines similarly situated.

Resulting differences of height.

From reciprocal zenith distances:

Stations.	Δh.	p.
Mount Lola to Mount Helena	1 519·64	0·6
Round Top to Mount Helena	1 888·34	0·8
Mount Lola to Mount Diablo	1 626·11	0·8
Round Top to Mount Diablo	2 011·37	1·5
Round Top to Mocho	1 931·00	0·9
Round Top to Mount Lola	378·86	8·4
Pine Hill to Sacramento	617·49	21·8
Monticello to Pine Hill	306·05	3·2
Vaca to Pine Hill	101·79	2·8
Jackson Butte to Pine Hill	76·63	14·8
Round Top to Pine Hill	2 538·79	11·8
Round Top to Jackson Butte	2 460·05	13·4
Mount Lola to Pine Hill	2 159·43	4·1
Mount Conness to Mount Diablo	2 708·18	0·2

From one zenith distance:

Stations.	Δh.	p.
Mount Helena to Pine Hill	666·87	0·7
Mount Diablo to Pine Hill	557·73	0·5
Yolo Base NW. to Pine Hill	578·60	3·5
Mount Helena to Marysville Butte	681·17	2·4
Mount Diablo to Marysville Butte	525·02	0·7
Yolo Base NW. to Marysville Butte	598·73	8·0
Monticello to Marysville Butte	285·53	4·3
Vaca to Marysville Butte	84·09	2·2
Yolo Base SE. to Marysville Butte	617·25	2·6
Mount Lola to Marysville Butte	2 131·91	1·4
Round Top to Marysville Butte	2 471·71	0·8
Round Top to Mount Conness	672·02	5·3
Mocho to Mount Conness	2 526·15	0·5

As already stated, the long lines stretching across the valley give too discordant results to be used, and the heights of Mount Lola and Round Top are made to depend entirely upon the intermediate station, Pine Hill. For its height we have six values, two of which are very doubtful and are therefore rejected.

		Δh	h	
	m.	*m.*	*m.*	*p.*
From Sacramento	10·57	+617·49 =	628·06	21·8
From Monticello	932·39	+306·05	626·34	3·2
From Vaca	729·75	+101·79	627·96	2·8
From Mount Helena	1 322·08	−666·87	655·21	0·7 reject.
From Mount Diablo	1 173·10	−557·73	615·37	0·5 reject.
From Yolo Base NW.	46·66	+578·60	625·26	3·5
	Weighted mean		627·56	

The station at Sacramento is the top of the circular base of the northeast post of the gilded iron fence, surrounding the statue in the capitol rotunda, presented to the State by Mr. D. O. Mills. It was connected by spirit levels in 1898 with a Central Pacific Railroad bench mark, of which the height was determined by the railroad engineers. The heights of the other stations are taken from the adjustment of heights of stations near the Coast Range.

For the determination of the heights of Mount Lola and Round Top, and incidentally of Jackson Butte, we have the following differences of height and observation equations for adjustment:

Stations.	Δh.	*p.*	Observation equations.	Adjusted Δh.	Discrepancy.
	m.			*m.*	*m.*
Jackson Butte to Pine Hill	76·63	14·8	$0=-0{\cdot}81+x_1$	77·28	0·65
Round Top to Pine Hill	2 538·79	11·8	$0=+1{\cdot}35-x_2$	2 538·04	0·75
Round Top to Jackson Butte	2 460·05	13·4	$0=+0{\cdot}05+x_1-x_2$	2 460·76	0·71
Round Top to Mount Lola	378·86	8·4	$0=+0{\cdot}14+x_2-x_3$	378·78	0·08
Mount Lola to Pine Hill	2 159·43	4·1	$0=+0{\cdot}99-x_3$	2 159·26	0·17

The solution of the normal equations from these observation equations gave the following results:

Station.	Assumed height.	Correction.	Adjusted height.	
	m.		*m.*	*Feet.*
Pine Hill			627·6 or	2 059
Jackson Butte	705	$x_1=-0{\cdot}16$	704·8	2 312
Round Top	3 165	$x_2=+0{\cdot}60$	3 165·6	10 386
Mount Lola	2 786	$x_3=+0{\cdot}82$	2 786·8	9 143

The height of Mount Lola from the railroad levels to Truckee ($h = 1\ 773{\cdot}66$ metres) and Assistant J. J. Gilbert's levels of 1898 from Truckee to Mount Lola ($\Delta h = 1\ 013{\cdot}87$ metres) is 2 787·5 metres.

For the height of Marysville Butte we have the values—

		m.		
From Mount Helena	1 322 ·08—	681 ·17 = 640 ·91		p=2 ·4
Mount Diablo	1 173 ·10—	525 ·02 = 648 ·08		0 ·7
Yolo Base Northwest	46 ·66+	598 ·73 = 645 ·39		8 ·0
Monticello	932 ·39—	285 ·53 = 646 ·86		4 ·3
Vaca	729 ·75—	84 ·09 = 645 ·66		2 ·2
Yolo Base Southeast	21 ·66+	617 ·25 = 638 ·91		2 ·6
Mount Lola	2 786 ·8 —2	131 ·91 = 654 ·9	rejected	1 ·4
Round Top	3 165 ·6 —2	471 ·71 = 693 ·9	rejected	0 ·8

Weighted mean 644 ·5 metres, or 2 114 feet.

G. DETERMINATION OF HEIGHTS OF TRIGONOMETRIC STATIONS IN THE ROCKY MOUNTAINS BETWEEN PIKES PEAK, COLORADO, AND ROUND TOP, SIERRA NEVADA, CALIFORNIA.

I. ABSTRACT OF REDUCED ZENITH DISTANCES.

Mount Lola. July, 1879. Vertical Circle, No. 80. J. F. Pratt, observer; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
10	Pah-Rah	90 31 24 ·8	—0 ·3	—0 ·2	90 31 24 ·3	547	12 ·6	4 ·936 44
12	Mount Como	90 22 53 ·3	—1 ·0	+0 ·5	90 22 52 ·8	546	12 ·5	4 ·951 80
11	Round Top	90 07 24 ·9	—0 ·6	+0 ·6	90 07 24 ·9	546	12 ·2	4 ·959 22

Observations between 5 hours 20 minutes and 9 hours a. m., and between 3 hours and 6 hours 25 minutes p. m.

Round Top. August, September, and October, 1879. Vertical Circle, No. 80. J. J. Gilbert and J. F. Pratt, observers; George Davidson, chief of party.

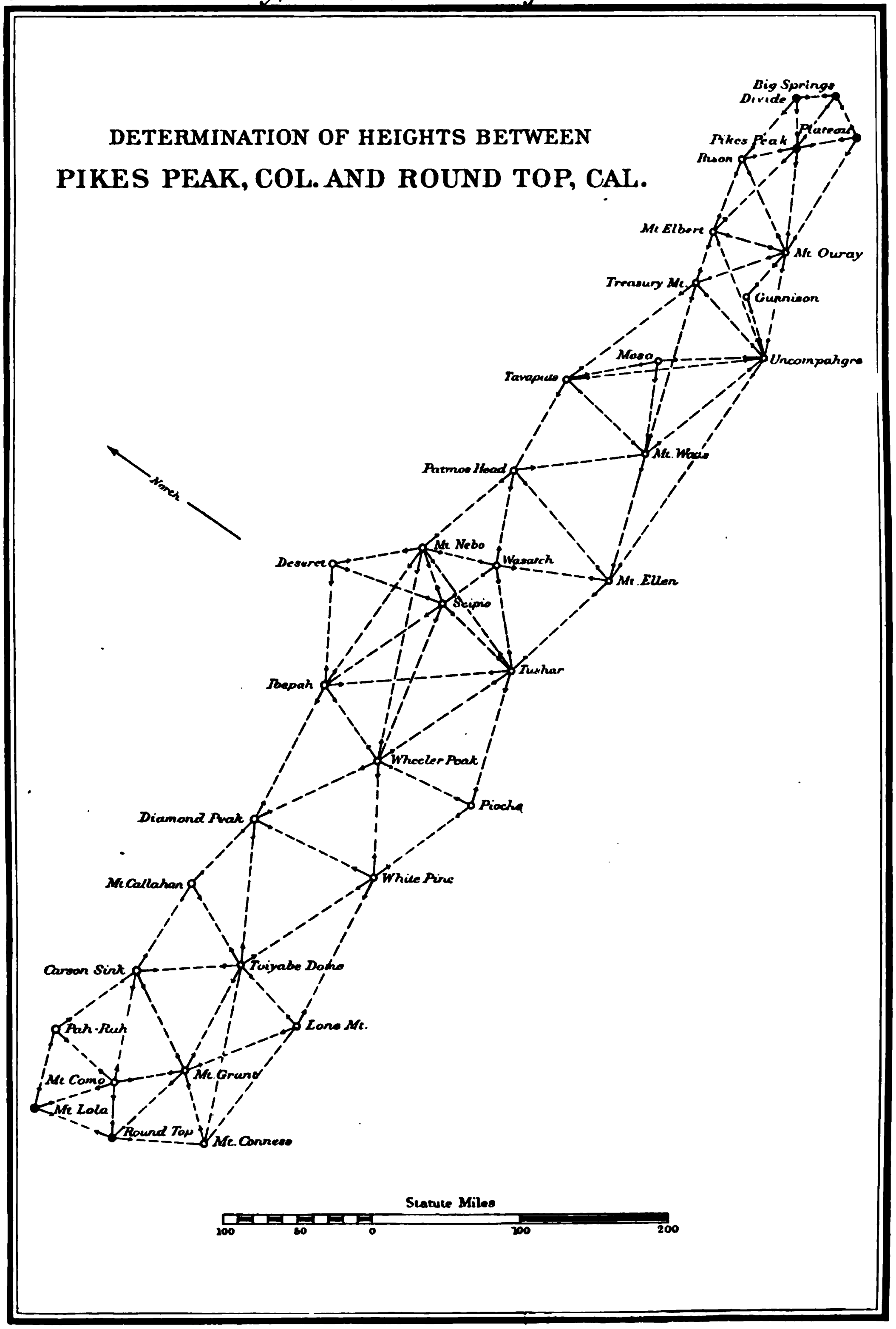
Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
19	Mount Lola	90 36 00 ·8	—0 ·2	—0 ·2	90 36 00 ·8	524	12 ·1	4 ·959 22
18	Mount Como	90 38 13 ·6	—2 ·3	+0 ·3	90 38 11 ·6	526	12 ·7	4 ·782 38
19	Mount Grant	90 16 45 ·7	+0 ·8	+0 ·1	90 16 46 ·6	526	12 ·7	5 ·024 71
20	Mount Conness	89 59 36 ·4	—1 ·7	- 0 ·1	89 59 34 ·6	525	12 ·2	4 ·989 14

Observations between 6 hours 20 minutes a. m. and 6 hours 30 minutes p. m.

Mount Conness. August and September, 1890. Vertical Circle, No. 80. J. J. Gilbert and I. Winston, observers; George Davidson, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
7	Mount Grant	90 34 04 ·1	+189 ·1	0 ·0	90 37 13 ·2	....	....	4 ·910 91
4	Mount Diablo	91 32 59 ·2	+ 67 ·5	—1 ·2	91 34 05 ·5	....	....	5 ·358 24

Observations between 11 hours 50 minutes a. m. and 12 hours 50 minutes p. m.


DETERMINATION OF HEIGHTS BETWEEN
PIKES PEAK, COL. AND ROUND TOP, CAL.
North
Big Springs
Divide
Plateau
Pikes Peak
Bison
Mt Elbert
Mt. Ouray
Treasury Mt.
Gunnison
Mesa
Uncompahgre
Tavaputs
Mt. Waas
Patmos Head
Mt Nebo
Deseret
Wasatch
Mt. Ellen
Scipio
Ibepah
Tushar
Wheeler Peak
Diamond Peak
Pioche
White Pine
Mt Callahan
Carson Sink
Toiyabe Dome
Pah-Rah
Lone Mt.
Mt Como
Mt. Grant
Mt Lola
Round Top
Mt. Conness
Statute Miles
100
50
0
100
200

Mount Como. August, September, October, and November, 1879. Vertical Circle, No. 100. W. Eimbeck and R. A. Marr, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
15	Round Top	89 50 56·3	−1·7	+0·1	89 50 54·7	550	18·1	4·782 38
14	Mount Grant	89 48 33·1	+0·7	+0·2	89 48 34·0	550	18·3	4·889 88
11	Carson Sink	90 31 29·9	+0·2	0·0	90 31 30·1	551	17·0	5·092 36
11	Pah-Rah	90 29 57·1	+2·5	−0·1	90 29 59·5	551	16·9	4·933 67
11	Mount Lola	90 19 58·5	−0·1	−0·1	90 19 58·3	551	17·9	4·951 80
8	Pilot Cone	90 49 33·9	−3·8	0·0	90 49 30·1	552	18·7	4·953 82
5	Mount Davidson	90 42 18·3	−0·2	−0·4	90 42 17·7	552	19·4	4·554 02

Observations between 11 hours 25 minutes a. m. and 6 hours 10 minutes p. m.

Pah-Rah. October and November, 1878. Vertical Circle, No. 100. W. Eimbeck, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
7	Mount Lola	90 09 13·4	−1·5	−0·1	90 09 11·8	566	7·7	4·936 44
8	Mount Como	90 11 07·6	−2·0	0·0	90 11 05·6	566	11·1	4·933 67
9	Carson Sink	90 19 57·0	−1·9	0·0	90 19 55·1	566	8·8	5·036 73
4	Mount Davidson	90 20 21·8	−3·3	0·0	90 20 18·5	565	4·7	4·751 17

Observations between 9 hours 30 minutes a. m. and 4 hours 6 minutes p. m.

Mount Grant. October and November, 1879. Vertical Circle, No. 100. W. Eimbeck and R. A. Marr, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
10	Round Top	90 33 49·1	−4·5	0·0	90 33 44·6	509	7·4	5·024 71
12	Carson Sink	90 49 40·8	−0·9	−0·1	90 49 39·8	509	4·9	5·087 38
10	Mount Como	90 48 35·4	+0·1	0·0	90 48 35·5	509	7·4	4·889 88
11	Lone Mountain	90 47 54·4	−1·3	+0·1	90 47 53·2	509	5·0	5·109 33
11	Mount Conness	90 02 23·5	−4·0	+0·2	90 02 19·7	510	4·5	4·910 91
11	Toiyabe Dome	90 25 52·6	−0·3	0·0	90 25 52·3	510	3·8	5·108 78
10	Pilot Cone	91 40 20·3	−5·8	+0·5	91 40 15·0	510	4·6	4·745 91
6	White Mountains, north peak.	89 55 59·3	−3·6	+0·3	89 55 56·0	511	4·7	4·952 75
6	Desatoiya	90 39 38·3	−0·4	−0·1	90 39 37·8	511	1·3	5·099 20
6	Volcano Peak	90 46 22·2	−5·5	−0·1	90 46 16·6	510	4·3	4·767 00

Observations between noon and 2 hours p. m.

Carson Sink. July, 1880. Vertical Circle, No. 100. W. Eimbeck and R. A. Marr, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
14	Pah-Rah	90 31 09·8	+ 1·4	+0·1	90 31 11·3	555	20·5	5·036 73
11	Mount Como	90 27 41·4	+ 0·5	+0·1	90 27 42·0	556	20·0	5·092 36
10	Mount Grant	90 08 23·8	+ 0·9	+0·2	90 08 24·9	555	21·2	5·087 38
11	Toiyabe Dome	89 59 25·0	+ 0·5	0·0	89 59 25·5	556	20·2	5·052 72
10	Mount Callahan	90 13 22·0	− 0·7	−0·1	90 13 21·2	556	20·8	5·045 90
12	Pilot Cone	90 50 04·4	− 3·0	−0·1	90 50 01·3	555	20·0	4·834 22
13	Desatoiya	89 45 05·4	+ 6·1	−0·1	89 45 11·4	556	20·6	4·677 53
5	Fair View	90 22 20·5	− 5·1	0·0	90 22 15·4	555	21·2	4·606 19
5	Indian Peak or Star Peak	90 14 35·5	− 2·0	−0·2	90 14 33·3	556	19·8	5·018 92
1	Mount Lincoln	90 52 39·8	−46·8	−5·4	90 51 47·6	555	22·8	3·645 96
6	Augusta Peak	89 21 44·4	− 7·5	−0·5	89 21 36·4	556	19·9	4·440 44

Observations between 11 hours 45 minutes a. m. and 2 hours 40 minutes p. m.

Mount Callahan. July and August, 1881. Vertical Circle, No. 100. R. A. Marr, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
14	Diamond Peak	90 19 08.2	+0.9	0.0	90 19 09.1	521	16.5	4.991 90
14	Carson Sink	90 40 05.1	+1.0	0.0	90 40 06.1	522	17.6	5.045 90
12	Toiyabe Dome	90 09 15.2	+1.2	+0.3	90 09 16.7	522	16.9	5.014 25
13	Bunker Hill	89 47 41.6	−5.0	+0.5	89 47 37.1	521	16.0	4.723 28
10	Desatoiya	90 22 11.1	−3.3	+0.1	90 22 07.9	522	17.1	4.899 26
10	Sharp Peak	90 22 10.3	−3.0	+0.1	90 22 07.4	521	16.9	4.938 46
8	Monitor	90 18 16.7	+0.8	+0.2	90 18 17.7	522	15.9	5.015 24
3	Shoshone, north peak	90 17 06.0	−3.4	+0.2	90 17 02.8	519	13.3	4.886 42
2	Mount Lewis	90 25 54.4	−3.4	−0.1	90 25 50.9	526	17.4	4.888 95
4	Broken Back	90 08 35.1	−4.7	+0.2	90 08 30.6	520	17.7	4.747 82
1	Granite Peak	90 26 36.6	−2.9	−0.1	90 26 33.6	523	19.8	4.948 73

Observations mostly btween 11 hours 45 minutes a. m. and 1 hour 15 minutes p. m.

Toiyabe Dome. August and September, 1880. Vertical Circle, No. 100. R. A. Marr and W. Eimbeck, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
17	Mount Grant	90 34 54.3	− 0.2	+0.2	90 34 54.3	492	9.4	5.108 78
13	Mount Callahan	90 41 05.4	− 0.6	+0.2	90 41 05.0	491	9.6	5.014 25
15	Pilot Cone	91 19 38.1	− 3.6	−0.5	91 19 34.0	492	9.6	4.980 34
13	Carson Sink	90 54 54.0	− 0.3	+0.1	90 54 53.8	492	10.0	5.052 72
15	Diamond Peak	90 45 27.2	0.0	0.0	90 45 27.2	493	11.8	5.194 91
14	Lone Mountain	90 52 45.2	− 0.2	+0.1	90 52 45.1	494	12.5	4.957 00
14	White Pine	90 43 56.8	− 0.8	−0.5	90 43 55.5	493	10.0	5.233 18
5	Mount Jefferson	90 08 07.5	− 9.3	−0.5	90 07 57.7	490	11.2	4.570 31
5	Fairview	91 04 14.7	− 4.2	−0.6	91 04 09.9	495	13.7	4.912 71
11	Bunker Hill	90 18 30.8	− 6.8	+0.3	90 18 24.3	493	10.9	4.704 31
14	Sharp Peak	90 41 38.3	− 3.4	−0.1	90 41 34.8	493	11.4	5.006 95
12	White Mountains, north peak	90 21 21.5	− 2.4	−0.4	90 21 18.7	493	10.3	5.149 18
12	Desatoiya	90 44 06.4	− 0.4	−0.3	90 44 05.7	493	11.5	4.837 38
13	Monitor	90 30 14.8	− 5.2	−0.1	90 30 09.5	493	9.8	4.820 66
3	Shoshone, north summit	90 50 25.4	− 9.3	−2.1	90 50 14.0	493	13.7	4.567 63
2	Shoshone, south peak	91 05 57.0	−11.2	−4.1	91 05 41.7	494	12.7	4.486 89

Observations between 11 hours 30 minutes a. m. and 2 hours 15 minutes p. m.

Lone Mountain. October and November, 1880. Vertical Circle, No. 100. W. Eimbeck and R. A. Marr, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
15	Mount Grant	90 12 15.4	+0.4	−0.3	90 12 15.5	547	2.0	5.109 33
12	Toiyabe Dome	89 50 13.0	+1.1	−0.5	89 50 14.6	548	1.7	4.957 00
12	White Pine	90 28 20.2	−0.2	+0.5	90 28 20.5	548	2.4	5.249 53
13	Monitor	90 11 41.5	+0.7	+0.5	90 11 42.7	547	2.1	5.073 19
12	White Mountains, south peak	89 11 21.7	−3.3	−1.5	89 11 16.9	547	3.9	4.901 96
8	White Mountains, north peak	89 20 46.5	−3.4	−1.3	89 20 41.8	546	5.3	4.895 27
8	Lion Saddle	90 22 09.9	−2.7	+0.4	90 22 07.6	548	1.7	4.993 38
6	Montezuma	90 29 12.5	−6.9	+0.1	90 29 05.7	546	2.1	4.584 29

Observations between 11 hours 45 minutes a. m. and 2 hours 15 minutes p. m.

Diamond Peak. August and September, 1881. Vertical Circle, No. 100. W. Eimbeck and R. A. Marr, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
14	White Pine	90 29 24·5	+ 6·1	+0·5	90 29 31·1	518	10·9	5·155 81
14	Wheeler Peak	90 17 22·8	+ 6·1	+0·4	90 17 29·3	520	13·6	5·163 98
13	Mount Callahan	90 28 00·9	+10·5	—0·1	90 28 11·3	521	13·7	4·991 90
13	Ibepah	90 30 05·4	+ 5·1	0·0	90 30 10·5	519	13·6	5·217 67
10	Toiyabe Dome	90 29 47·5	+ 6·2	+0·2	90 29 53·9	517	9·8	5·194 91
11	Sharp Peak	90 23 19·9	+ 9·5	+0·2	90 23 29·6	516	10·2	4·787 53
12	Monitor	90 23 31·9	+ 8·6	+0·3	90 23 40·8	521	13·5	5·033 68
3	Prospect Peak	90 55 21·2	+27·1	—1·5	90 55 46·8	519	8·9	4·334 28
5	Mount Hamilton	90 07 48·6	+12·8	+0·5	90 08 01·9	518	11·2	4·661 31
6	Duckwater	90 28 15·7	+ 7·1	+0·3	90 28 23·1	516	9·7	4·915 48
5	Broken Back	90 16 54·3	+ 9·7	+0·1	90 17 04·1	517	11·1	4·777 99
6	Ward	90 18 56·1	+ 6·2	+0·3	90 19 02·6	519	10·8	4·974 44

Observations mostly between 11 hours 50 minutes a. m. and 2 hours p. m.; a few between 4 hours 15 minutes and 5 hours 30 minutes p. m.

White Pine. November and December, 1881. Vertical Circle, No. 100. W. Eimbeck and R. A. Marr, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
13	Lone Mountain	90 53 52·3	+1·5	—0·1	90 53 53·7	504	—0·4	5·249 53
13	Pioche	90 50 35·6	+1·6	0·0	90 50 37·2	505	+0·2	5·121 78
11	Diamond Peak	90 38 21·8	+1·9	+0·1	90 38 23·8	505	+1·1	5·155 81
11	Wheeler Peak	90 15 16·7	+1·3	+0·2	90 15 18·2	505	+0·7	5·104 32
10	Toiyabe Dome	90 36 50·8	—0·8	0·0	90 36 50·0	505	—0·1	5·233 18
11	Duckwater	90 12 02·6	—2·0	+0·2	90 12 00·8	504	0·0	4·818 80
11	Lion Saddle	90 46 27·6	—1·6	0·0	90 46 26·0	504	—0·3	4·906 50
11	Monitor	90 29 46·4	+1·9	0·0	90 29 48·3	505	+0·1	5·041 26
11	Ward	90 27 16·6	—1·3	+0·1	90 27 15·4	504	0·5	5·001 54
11	Sharp Peak	90 37 30·4	—1·2	+0·1	90 37 29·3	504	—0·6	5·051 53
5	Mount Hamilton	90 29 27·3	—1·3	+0·1	90 29 26·1	504	—1·1	5·006 15
3	Snow Peak or Indian Peak	90 44 23·6	—0·9	0·0	90 44 22·7	507	—3·3	5·153 55
3	Mount Grafton	90 22 20·0	—1·7	+0·1	90 22 18·4	500	—1·9	4·892 68
3	Hot Creek, north summit	90 32 08·8	—1·7	0·0	90 32 07·1	500	—2·3	4·884 38

Observations between 11 hours 5 minutes a. m. and 1 hour 50 minutes p. m.

Wheeler Peak. November, 1882. Vertical Circle, No. 100. R. A. Marr, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
10	Diamond Peak	90 51 26·9	+ 5·6	−0·5	90 51 32·0	469	−5·8	5·163 98
9	Pioche	91 05 58·6	+ 7·0	0·0	91 06 05·6	469	−6·2	5·054 23
9	Ibepah	90 33 24·1	+ 6·9	+0·3	90 33 31·3	469	−5·6	4·997 80
8	White Pine	90 44 05·3	+ 6·5	−0·5	90 44 11·3	469	−5·4	5·104 32
6	Beaver*	90 47 08·5	+ 4·6	+0·8	90 47 13·9	470	−6·6	5·245 32
3	Mount Nebo	91 01 00·7	+ 3·3	+0·9	91 01 04·9	470	−5·4	5·376 16
8	Ward	90 53 24·2	+ 8·6	+1·3	90 53 34·1	469	−5·6	4·732 72
7	Mount Moriah	90 38 45·5	+13·9	−0·8	90 38 58·6	469	−5·6	4·524 01
6	Mount Grafton	90 54 54·6	+ 9·4	+1·5	90 55 05·5	469	−5·9	4·694 35
6	Snow Peak or Indian Peak	90 59 19·3	+ 5·3	−0·2	90 59 24·4	468	−5·2	4·946 72
6	Sawtooth Mountain	91 03 06·0	+ 5·8	−0·8	91 03 11·0	469	−5·6	4·904 24
4	Shell Creek North	90 35 16·9	+ 8·7	+0·1	90 35 25·7	468	−6·5	4·728 36

Observations between 11 hours a. m. and 4 hours 15 minutes p. m.

Pioche. September, 1883. Vertical Circle, No. 100. G. F. Bird, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
10	White Pine	90 11 50·6	+2·5	+0·1	90 11 53·2	555	19·0	5·121 78
10	Wheeler Peak	89 47 42·7	+3·2	+0·8	89 47 46·7	555	20·2	5·054 23
10	Tushar	90 13 05·4	+1·2	+0·2	90 13 06·8	555	20·1	5·180 22
10	Snow Peak or Indian Peak	89 38 08·7	−1·0	+1·5	89 38 09·2	555	18·7	4·541 79
10	Highland or Meadow Valley	89 59 07·0	−0·7	−0·2	89 59 06·1	554	18·7	4·675 93
10	Mount Grafton	90 00 24·2	−0·4	+0·5	90 00 24·3	555	18·8	4·995 36
9	White Rock	90 02 43·5	−1·2	+0·3	90 02 42·6	555	19·4	4·475 28
2	Pioche Peak	90 49 33·8	−0·9	+0·3	90 49 33·2	555	21·1	4·582 89

Observations between 11 hours 35 minutes a. m. and 1 hour 20 minutes p. m.

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*Beaver was not occupied for vertical measures, but it may be regarded as an eccentric station to Tushar and the above zenith distance corrected accordingly. The difference of height of Beaver and Tushar was computed from the observed zenith distance at Tushar and an assumed coefficient of refraction (0·055), and Tushar was found to be 18·36 metres higher than Beaver. From the triangulation we have Wheeler Peak 1 029 metres nearer to Beaver than to Tushar. The zenith distance at Wheeler Peak of Beaver was first corrected for the above difference in height in the usual manner, and then for the difference in distance by the expression $\frac{d \cos \zeta}{s \sin 1''}$, in which d is the difference in distance; ζ is the zenith distance at Tushar of Wheeler Peak, and s is the distance from Wheeler Peak to Beaver. The resulting zenith distance of Tushar is—

		° ′ ″	″	″	° ′ ″	mm.	°	
6	Tushar	90 47 13·9	−21·5	+13·0	90 47 05·4	470	−6·6	5·247 85

Tushar. August and September, 1885. Vertical Circle, No. 100. G. F. Bird, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
10	Pioche	90 59 32·7	+ 2·2	0·0	90 59 34·9	492	8·7	5·180 22
11	Mount Ellen	90 39 20·2	+ 2·4	0·0	90 39 22·6	491	8·4	5·157 43
10	Wheeler Peak	90 36 55·1	+ 2·2	+0·1	90 36 57·4	492	9·3	5·247 85
6	Ibepah	90 49 08·3	+ 1·2	+0·1	90 49 09·6	494	11·6	5·308 77
10	Mount Nebo	90 41 10·9	+ 2·0	+0·2	90 41 13·1	493	10·1	5·215 52
11	Beaver	90 21 04·0	+168·5	+3·9	90 23 56·4	492	9·5	3·433 04
14	Antelope Mountain	90 51 15·3	− 0·1	+0·1	90 51 15·3	494	9·7	5·124 10
13	Scipio	90 49 27·4	+ 1·7	+0·1	90 49 29·2	492	9·2	5·039 46
12	Wasatch	90 36 37·8	+ 3·4	−0·1	90 36 41·3	491	9·4	5·055 35
13	Sevier	90 50 24·0	− 0·2	0·0	90 50 23·8	492	9·1	5·072 47
13	Frisco	90 52 07·2	− 0·2	0·0	90 52 07·0	492	9·4	4·887 56
13	Lone Tree	90 48 11·8	− 0·3	−0·1	90 48 11·4	492	9·4	4·832 79
12	Mount Hilgard	90 25 14·8	− 0·2	0·0	90 25 14·6	492	8·8	4·861 57
13	Mooseneah	90 36 07·2	− 0·2	+0·1	90 36 07·1	492	8·9	4·999 17
10	Sanpete	90 41 07·0	+ 2·7	+0·1	90 41 09·8	493	9·6	5·138 09
10	Delano	89 55 23·8	+ 75·2	−0·5	89 56 38·5	492	9·5	3·820 70
12	Milford	90 24 13·8	− 0·5	0·0	90 24 13·3	492	10·3	4·549 36

Observations between 11 hours a. m. and 2 hours p. m., except a few on Ibepah and one on Wheeler at about 4 hours p. m.

Scipio. September, 1884. Vertical Circle, No. 100, and Theodolite, No. 5. W. Eimbeck and G. F. Bird, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
12*	Tushar	90 03 12·9	+ 1·0	−0·3	90 03 13·6	537	12·4	5·039 46
13*	Mount Nebo	89 36 27·9	+ 3·9	+0·2	89 36 32·0	536	11·9	4·777 36
14*	Wasatch	89 56 33·0	+ 3·6	−0·5	89 56 36·1	536	11·8	4·857 12
9*	Ibepah	90 20 49·0	− 0·7	+0·3	90 20 48·6	537	11·5	5·189 81
10*	Deseret	90 18 31·2	− 0·9	+0·4	90 18 30·7	537	11·8	5·092 58
2	Wheeler Peak	90 25 39·4	− 0·6	+0·2	90 25 39·0	536	9·8	5·273 06
12*	Sanpete	89 55 45·0	+ 6·7	−0·4	89 55 51·3	537	12·5	4·840 14
10*	Salt Creek	90 06 13·6	− 2·2	0·0	90 06 11·4	536	12·3	4·699 44
7*	Lone Tree	90 02 36·5	− 2·4	−0·4	90 02 33·7	537	12·3	4·649 80
10	South Juab Base	92 47 55·9	+30·6	+0·5	92 48 27·0	536	12·3	4·471 73
11	Levan	90 47 33·4	+11·0	−0·2	90 47 44·2	536	11·8	4·565 72
10	Cedar Hill	91 42 34·4	+13·3	−0·1	91 42 47·6	537	12·3	4·534 76
10*	Sevier	90 26 15·5	− 1·0	+0·1	90 26 14·6	537	10·8	5·030 92
8	Antelope Mountain	90 23 13·6	− 1·1	+0·3	90 23 12·8	537	11·1	4·980 11
7	Milford	90 30 58·9	− 0·9	0·1	90 30 57·9	538	11·9	5·092 58
6	Frisco	90 32 32·7	− 0·8	0·0	90 32 31·9	538	10·9	5·129 37
7*	Lone Peak	90 19 13·0	− 0·8	+0·2	90 19 12·4	538	12·2	5·119 63
8	Mooseneah	89 56 24·0	− 1·6	−0·6	89 56 21·8	537	12·1	4·827 52
3†	Beaver	90 04 48·8	− 3·3	0·0	90 04 45·5	536	11·8	5·048 23
3†	Mount Hilgard	90 01 42·7	− 4·0	0·0	90 01 38·7	536	11·8	4·973 97
2†	Herriman	90 19 32·3	− 3·3	0·0	90 19 29·0	536	9·8	5·059 56
3†	Springville Peak	90 13 26·3	− 3·4	0·0	90 13 22·9	536	11·2	5·040 37

Observations between 10 hours 30 minutes a. m. and 4 hours p. m.

* Including observations of micrometric differences of heights. † By micrometric differences only.

Ibepah. August and September, 1889. Vertical Circle, No. 100 P. A. Welker, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
13	Wheeler Peak	90 13 47·8	+ 4·0	− 0·2	90 13 51·6	494	13·6	4·997 80
13	Deseret	90 39 44·9	+ 2·2	+ 0·1	90 39 47·2	495	12·0	5·116 02
14	Pilot Peak	90 42 48·5	+ 1·4	0·0	90 42 49·9	495	10·4	5·124 32
9	Tushar	90 48 44·5	+ 1·3	0·0	90 48 45·8	494	11·1	5·308 77
5	Ogden Peak	91 06 38·1	+ 1·7	+ 0·1	91 06 39·9	494	12·4	5·362 23
9	Mount Nebo	90 45 19·5	+ 1·6	+ 0·2	90 45 21·3	495	12·0	5·265 70
11	Diamond Peak	90 48 59·0	+ 1·0	− 0·1	90 48 59·9	494	7·6	5·217 67
5	Mount Moriah	90 16 28·7	0·0	− 0·1	90 16 28·6	493	14·6	4·820 36
5	Antelope Mountain	90 52 40·2	0·0	0·0	90 52 40·2	494	14·3	4·852 74
5	Sawtooth Mountain or Sevier	90 50 15·4	0·0	0·0	90 50 15·4	494	14·4	4·943 55
5	Shell Creek Mountain, South	90 23 14·9	0·0	− 0·1	90 23 14·8	494	13·8	4·902 98
3	Ibepah post-office	94 39 55·9	+31·4	− 1·5	94 40 25·8	496	15·3	4·418 21
3	Desert Peak	91 11 45·2	0·0	0·0	91 11 45·2	493	11·7	5·198 28
3	Red Chief	92 32 23·5	− 0·8	+20·1	92 32 42·8	494	14·7	3·536 23
16	Azimuth Mark	90 32 50·0	+143·1	− 4·9	90 35 08·2	....	....	3·487 65

Observations between 11 hours 30 minutes a. m. and 1 hour p. m., and between 4 hours 30 minutes and 6 hours 20 minutes p. m.

Pilot Peak. July, 1889. Vertical Circle, No. 100. W. Eimbeck and C. L. Brackett, observers; W. Eimbeck, chief of party. August, 1892. Vertical Circle, No. 44. O. B. French, observer; W. Eimbeck, chief of party. August, 1897. Vertical Circle, No. 28. H. C. Denson, observer; P. A. Welker, chief of party.

Number of days.	Object observed.	Year	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
			° ′ ″	″	″	° ′ ″	mm.	°	
10	Azimuth Mark,	1889	92 20 09·4	+90·8	+11·3	92 21 51·5			3·364 18
12	Ibepah,	1889	90 21 16·9	+ 1·2	+ 0·1	90 21 18·2	519	17·7	
13	Ibepah,	1892	90 21 14·4	− 0·5	+ 0·1	90 21 14·0	520	17·8	
25	Ibepah, mean					90 21 16·0			5·124 32
18	Deseret,	1889	90 30 35·0	+ 2·2	+ 0·1	90 30 37·3	520	18·1	
13	Deseret,	1892	90 30 28·6	− 0·5	+ 0·1	90 30 28·2	520	8·2	
31	Deseret, mean					90 30 33·5			5·138 36
7	Mount Nebo,	1889	90 52 02·7	+ 1·0	+ 0·1	90 52 03·8	520	18·9	5·376 16
6	Ogden Peak,	1889	90 51 00·0	+ 1·5	+ 0·1	90 51 01·6	519	18·9	
13	Ogden Peak,	1892	90 50 44·5	+ 1·8	0·0	90 50 46·3	520	17·8	
6	Ogden Peak,	1897	90 50 40·4	+ 0·6	0·0	90 50 41·0	520	17·6	
25	Ogden Peak, mean					90 50 48·7			5·268 25
8	Wheeler Peak,	1889	90 44 01·8	+ 1·2	+ 0·1	90 44 03·1	530	18·1	5·355 83
4	Tecoma R.R. sign	1889	93 14 12·1	+18·6	+ 1·4	93 14 32·1	521	19·8	
2	Tecoma R.R. sign	1892	93 13 47·1	+19·7	+ 1·8	93 14 08·6	520	17·3	
6	Tecoma R.R. sign mean					93 14 24·3			4·521 31
3	Desert Peak,	1889	91 17 27·8	− 1·7	− 0·1	91 17 26·0	521	20·2	4·794 68
13	Promontory,	1892	91 04 15·7	+ 1·9	0·0	91 04 17·6	520	18·1	5·153 74
12	Antelope,	1892	91 04 54·3	+ 1·6	0·0	91 04 55·9	519	16·2	5·195 24

Observations in 1889 between noon and 2 hours p. m. and between 4 hours 45 minutes and 6 hours 45 minutes p. m.; in 1892 between 11 hours 40 minutes a. m. and 1 hour and 20 minutes p. m., and between 4 hours 40 minutes and 6 hours 25 minutes p. m.; in 1897 about noon.

Deseret. September, 1887. Vertical Circle, No. 100. J. H. Turner, observer; W. Eimbeck, chief of party. September, 1892. Vertical Circle, No. 44. O. B. French, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.		Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
			° ′ ″	″	″	° ′ ″	mm.	°	
14	Pilot Peak,	1887	90 35 04·8	+ 0·3	− 0·1	90 35 05·0	510	11·7	
8	Pilot Peak,	1892	90 35 22·1	− 1·3	− 0·1	90 35 20·7	514	13·5	
22	Pilot Peak, mean					90 35 10·7			5·138 36
14	Ogden Peak,	1887	90 39 25·7	+ 0·5	0·0	90 39 26·2	510	12·1	
15	Ogden Peak,	1892	90 39 30·9	+ 2·0	0·0	90 39 32·9	514	13·1	
29	Ogden Peak, mean					90 39 29·7			5·014 73
15	Ibepah,	1887	90 22 33·6	+ 0·2	0·0	90 22 33·8	512	11·3	
9	Ibepah,	1892	90 22 55·8	− 1·4	0·0	90 22 54·4	514	13·4	
24	Ibepah, mean					90 22 41·5			5·116 02
14	Antelope,	1887	91 26 23·4	+ 1·9	+ 0·2	91 26 25·5	512	12·2	
14	Antelope,	1892	91 26 24·4	+ 2·3	+ 0·2	91 26 26·9	514	13·1	
28	Antelope, mean					91 26 26·2			4·817 54
15	Mount Nebo,	1887	90 15 59·7	+ 0·2	+ 0·1	90 16 00·0	512	11·9	5·011 89
15	Draper,	1887	90 42 07·4	− 0·7	0·0	90 42 06·7	509	11·7	4·853 89
14	Onaqui,	1887	92 07 34·7	+20·0	+ 2·5	92 07 57·2	509	12·4	4·201 90
14	Oquirrh,	1887	90 52 37·3	− 6·3	0·0	90 52 31·0	512	12·8	4·612 08
7	Grantsville,	1887	95 47 52·2	+13·1	+ 2·9	95 48 08·2	513	13·8	4·309 91
5	Scipio,	1887	90 40 54·3	− 2·0	+ 0·1	90 40 52·4	511	11·9	5·092 59
7	Lake Shore Bend at Grantsville,	1887	94 11 47·0	+ 2·5	+ 1·6	94 11 51·1	512	12·3	4·464 26
2	Herriman,	1887	90 21 40·9	− 6·8	0·0	90 21 34·1	514	14·1	5·561 96
16	Waddoup,	1892	91 47 37·0	+ 2·0	+ 0·1	91 47 39·1	514	13·0	4·902 28
16	Promontory,	1892	91 11 43·0	+ 1·5	+ 0·1	91 11 44·6	514	13·2	4·976 45

Observations in 1887 mostly between noon and 2 hours p. m., a few between 2 hours p. m. and 3 hours p. m., and a few between 4 hours p. m. and 5 hours p. m.; in 1892 between noon and 1 hour p. m. and between 5 hours p. m. and 6 p. m.

Ogden Peak. September and October, 1888. Vertical Circle, No. 100. E. L. Taney, observer; W. Eimbeck, chief of party. June, 1891. Vertical Circle, No. 63. P. A. Welker, observer; W. Eimbeck, chief of party. July, 1896. Vertical Circle, No. 28. C. C. Yates, observer; W. Eimbeck, chief of party. September, 1897. Vertical Circle, No. 28. H. C. Denson, observer; P. A. Welker, chief of party.

Number of days.	Object observed.		Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
			° ′ ″	″	″	° ′ ″	mm.	°	
12	Draper,	1888	90 21 48·2	+ 2·1	+0·1	90 21 50·4	542	15·2	4·884 10
15	Oquirrh,	1888	90 19 49·5	+ 4·3	0·0	90 19 53·8	542	15·3	4·845 11
14	Mount Nebo,	1888	90 21 20·9	+ 1·3	+0·1	90 21 22·3	542	13·0	5·189 17
13	Antelope,	1888	91 29 43·6	+21·7	+0·1	91 30 05·4	542	14·8	
6	Antelope,	1896	91 30 09·1	− 6·2	0·0	91 30 02·9	541	17·1	
19	Antelope, mean					91 30 04·6			4·585 98
14	North Ogden,	1888	89 56 26·5	+28·6	−0·3	89 56 54·8	542	15·1	4·285 45
14	Deseret,	1888	90 09 52·7	+ 2·4	0·0	90 09 55·1	542	15·0	5·014 73
11	U. S. Engineers' Observatory,	1888	99 20 06·6	−40·3	+21·2	99 19 47·5	542	16·6	
6	U. S. Engineers' Observatory,	1891	99 19 52·5	− 6·8	0·0	99 19 45·7		8·6	
17	U. S. Engineers' Observatory, mean					99 19 46·9			3·986 32
12	Pilot Peak,	1888	90 37 28·3	+ 0·9	−0·1	90 37 29·1	542	13·4	
11	Pilot Peak,	1897	90 37 15·7	− 0·1	0·0	90 37 15·6	539	10·4	
23	Pilot Peak, mean					90 37 22·6			5·268 25
15	City Creek,	1888	91 32 10·3	+30·7	−0·4	91 32 40·6	542	12·8	4·639 59
4	Ibepah,	1888	90 43 26·5	+ 0·8	0·0	90 43 27·3	541	12·3	5·362 23
8	Salt Lake SE. Base,	1896	94 28 18·3	−10·9	0·0	94 28 07·4	541	16·7	4·328 53
8	Salt Lake NW. Base,	1896	94 23 01·3	−17·0	0·0	94 22 44·3	541	16·9	4·336 12
8	Waddoup,	1896	92 58 16·3	+ 1·7	0·0	92 58 18·0	541	16·9	4·512 42
5	Promontory,	1896	91 18 13·5	+ 0·9	0·0	91 18 14·4	541	18·2	4·666 30

Observations in 1888 between 11 hours 30 minutes a. m. and 1 hour 45 minutes p. m., and between 3 hours 50 minutes and 6 hours p. m.; in 1891 between 11 hours 50 minutes a. m. and 2 hours 30 minutes p. m.; in 1896 between 11 hours 45 minutes a. m. and 1 hour 10 minutes p. m.; in 1897 about noon.

*Ogden, United States Engineers' Station.** June, 1891. Vertical Circle, No. 63. W. Eimbeck, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
6	Ogden Peak	80 44 10·1	+34·1	0·0	80 44 44·2	647	23·6	3·986 32
6	Antelope	88 59 50·6	− 2·2	0·0	88 59 48·4	647	22·6	4·533 40
4	North Ogden	84 18 16·5	+27·7	0·0	84 18 44·2	645	23·7	4·208 70
2	Railroad Crossing	91 20 06·0	−37·0	0·0	91 19 29·0	652	21·6	2·998 86

Observations between 11 hours 20 minutes a. m. and 6 hours 50 minutes p. m.

* West pier of observatory.

City Creek. May and June, 1893. Vertical Circle, No. 44. R. L. Faris, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
5	Antelope	89 53 36·8	+ 8·1	0·0	89 53 44·9	*587	14·1	4·519 34
5	Ogden Peak	88 48 16·0	− 3·0	0·0	88 48 13·0	*587	14·1	4·639 59
4	Temple Block†	97 25 32·5	−66·5	0·0	97 24 26·0	*587	15·1	3·631 26
5	Temple, ball	96 45 58·4	−68·0	0·0	96 44 50·4	*587	14·4	3·621 58
5	Temple, figure	96 44 02·6	−68·0	0·0	96 42 54·6	*587	14·5	3·621 58

Observations between noon and 2 hours p. m.

Antelope. October, 1892. Vertical Circle, No. 44. O. B. French, observer; W. Eimbeck, chief of party. June and July, 1896. Vertical Circle, No. 28. P. A. Welker and C. C. Yates, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
16	Promontory, 1892	90 09 27·6	+ 7·7	−0·1	90 09 35·2	601	13·0	
9	Promontory, 1896	90 09 48·4	+ 0·3	0·0	90 09 48·7	603	26·7	
25	Promontory, mean				90 09 40·1			4·613 25
17	Ogden Peak, 1892	88 47 58·2	+ 0·7	+0·3	88 47 59·2	601	13·2	
9	Ogden Peak, 1896	88 48 13·8	+ 1·5	0·0	88 48 15·3	603	26·3	
26	Ogden Peak, mean				88 48 04·8			4·585 98
16	Waddoup, 1892	91 31 59·3	+ 9·9	−1·3	91 32 07·9	602	13·4	
9	Waddoup, 1896	91 32 26·5	− 7·6	0·0	91 32 18·9	604	26·3	
25	Waddoup, mean				91 32 11·9			4·453 18
13	Deseret, 1892	89 04 29·4	+ 3·5	0·0	89 04 32·9	602	12·7	4·817 54
10	Pilot Peak, 1892	90 08 41·0	+ 1·1	−0·2	90 08 41·9	603	9·7	5·195 24
5	Desert Peak, 1892	90 18 43·5	− 1·3	−0·2	90 18 42·0	604	7·8	4·999 86
5	Oquirrh, 1892	88 54 17·5	− 3·2	+0·7	88 54 15·0	600	10·3	4·588 36
5	Draper, 1892	89 27 45·3	− 2·0	+0·5	89 27 43·8	601	10·4	4·789 21
5	Springville Peak, 1892	89 34 19·1	− 1·3	−0·4	89 34 18·2	600	12·5	4·988 09
5	Onaqui, 1892	89 20 54·1	− 2·4	−0·1	89 20 51·6	601	10·8	4·717 95
7	City Creek, 1892	90 21 33·9	− 3·8	−0·1	90 21 30·0	604	12·1	4·519 34
7	Temple, east spire, 1892	91 10 07·9	− 3·6	−0·8	91 10 03·5	604	8·5	4·539 73
9	Salt Lake SE. Base, 1896	92 17 44·9	+26·9	0·0	92 18 11·8	603	26·4	4·270 60
9	Salt Lake NW. Base, 1896	92 15 43·1	+81·2	0·0	92 17 04·3	604	25·9	4·271 15

Observations in 1892 between 11 hours 30 minutes a. m. and 1 hour p. m. and between 4 hours 5 minutes and 5 hours 25 minutes p. m.; in 1896 between 11 hours 10 minutes a. m. and 1 hour 16 minutes p. m.

*Aneroid.

† White band 0·202 metre above the bottom doorstep at the east entrance to the Salt Lake City Mormon Temple.

Salt Lake Northwest Base. August, 1896. Vertical Circle, No. 37. W. Eimbeck, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
7	Promontory	88 53 48·1	− 30·1	0·0	88 53 18·0	653	31·7	4·521 20
7	Ogden Peak	85 47 44·8	− 20·0	0·0	85 47 24·8	653	31·7	4·336 12
8	Antelope	87 52 19·2	− 32·9	0·0	87 51 46·3	653	32·4	4·271 15
5	Salt Lake SE. Base	89 59 39·8	+273·0	0·0	90 04 12·8	652	33·9	4·049 17

Observations between noon and 1 hour p. m., and between 4 hours 25 minutes and 6 hours 10 minutes p. m.

Waddoup. May and June, 1892. Vertical Circles, Nos. 63 and 44. W. Eimbeck, R. L. Faris, and O. B. French, observers; W. Eimbeck, chief of party. June and July, 1896. Vertical Circle, No. 37. W. Eimbeck, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
18	Ogden Peak, 1892	87 17 01·0	+12·2	+1·2	87 17 14·4	650	23·1	
8	Ogden Peak, 1896	87 17 13·3	+ 0·3	0·0	87 17 13·6	652	30·4	
26	Ogden Peak, mean				87 17 14·2			4·512 42
15	Antelope, 1892	88 40 37·5	+12·4	+0·3	88 40 50·2	650	22·6	
8	Antelope, 1896	88 40 51·0	− 8·4	0·0	88 40 42·6	652	31·0	
23	Antelope, mean				88 40 47·6			4·453 18
16	Deseret, 1892	88 49 56·9	+ 2·9	−0·1	88 49 59·7	650	23·4	4·902 28
17	Promontory, 1892	89 35 30·3	+ 3·1	+0·2	89 35 33·6	650	20·4	
8	Promontory, 1896	89 35 27·3	− 1·0	0·0	89 35 26·3	652	30·8	
25	Promontory, mean				89 35 31·3			4·795 00
7	Salt Lake SE. Base, 1896	90 06 44·8	+62·6	0·0	90 07 47·4	652	31·1	4·262 74

Observations in 1892 between 11 hours 25 minutes a. m. and 2 hours p. m., and between 4 hours 45 minutes and 6 hours 40 minutes p. m.; in 1896 between 11 hours 45 minutes a. m. and 1 hour 20 minutes p. m., and between 3 hours 50 minutes and 6 hours 1 minute p. m.

Salt Lake Southeast Base. July, 1896. Vertical Circle, No. 37. W. Eimbeck and J. J. Gilbert, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	*P.*	*T* (*c.*)	Log *s.*
		° ′ ″	″	″	° ′ ″	*mm.*	°	
7	Antelope	87 51 04·9	− 31·1	0·0	87 50 33·8	652	27·6	4·270 60
6	Ogden Peak	85 42 42·8	− 46·7	0·0	85 41 56·1	651	28·6	4·328 53
7	Salt Lake NW. Base	89 55 25·7	+350·4	0·0	90 01 16·1	652	27·4	4·049 17
3	Waddoup	90 01 37·4	− 30·5	0·0	90 01 06·9	652	30·0	4·262 74

Observations between noon and 12 hours 40 minutes p. m., and between 5 hours and 6 hours 1 minute p. m.

Promontory. July, 1892. Vertical Circle, No. 44. O. B. French, observer; W. Eimbeck, chief of party. August, 1896. Vertical Circle, No. 28. C. C. Yates, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.		Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
			° ′ ″	″	″	° ′ ″	mm.	°	
16	Deseret,	1892	89 33 18.4	+ 6.4	+0.4	89 33 25.2	603	25.9	4.976 45
16	Waddoup,	1892	90 53 17.0	+ 11.6	−0.1	90 53 28.5	603	25.6	
6	Waddoup,	1896	90 53 22.1	+ 0.9	0.0	90 53 23.0	603	24.8	
22	Waddoup, mean					90 53 27.0			4.795 00
15	Ogden Peak,	1892	89 03 13.8	+ 11.3	0.0	89 03 25.1	603	25.6	
5	Ogden Peak,	1896	89 03 31.1	− 0.7	0.0	89 03 30.4	603	25.2	
20	Ogden Peak, mean					89 03 26.4			4.666 30
14	Antelope,	1892	90 09 13.4	+ 18.5	+0.1	90 09 32.0	603	25.3	
6	Antelope,	1896	90 09 37.3	− 1.6	0.0	90 09 35.7	603	24.8	
20	Antelope, mean					90 09 33.1			4.613 25
15	Pilot Peak,	1892	90 03 31.8	+ 4.7	+0.1	90 03 36.6	603	27.6	5.153 74
5	North Ogden,	1892	88 45 19.4	− 7.5	−0.4	88 45 11.5	603	27.6	4.592 36
6	Salt Lake NW. Base,	1896	91 20 24.5	+105.8	0.0	91 22 10.3	603	24.8	4.521 20

Observations in 1892 between noon and 1 hour 40 minutes p. m., and between 4 hours 45 minutes and 6 hours 45 minutes p. m.; in 1896 between 11 hours 55 minutes a. m. and 1 hour p. m.

Mount Nebo. June, July, and August, 1887. Vertical Circle, No. 100. J. H. Turner, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
13	Scipio	90 52 00.3	+ 5.0	−0.1	90 52 05.2	497	12.8	4.777 36
14	Deseret	90 33 17.6	− 0.1	0.0	90 33 17.5	498	13.4	5.011 89
13	Draper	90 53 04.8	+ 1.4	0.0	90 53 06.2	497	13.4	4.892 87
12	Ogden Peak	90 52 52.7	+ 1.1	0.0	90 52 53.8	498	14.2	5.189 17
16	Oquirrh	90 50 31.8	+ 2.5	0.0	90 50 34.3	497	13.6	4.982 77
17	Onaqui	90 52 27.3	+ 2.2	0.0	90 52 29.5	497	13.4	5.056 23
9	Pilot Peak	91 02 04.9	+ 0.6	0.0	91 02 05.5	498	14.3	5.376 16
13	Wasatch	90 29 16.8	+ 3.4	0.0	90 29 20.2	497	13.5	4.912 72
9	Ibepah	90 43 00.3	+ 0.6	+ 0.1	90 43 01.0	498	13.7	5.265 70
13	Tushar	90 37 56.8	+ 1.0	+ 0.1	90 37 57.9	497	13.6	5.215 52
10	Patmos Head	90 47 43.6	− 0.9	0.0	90 47 42.7	498	13.0	5.110 74
4	Wheeler Peak	90 51 48.7	− 0.2	+ 0.1	90 51 48.6	497	11.0	5.376 16
6	Sanpete	90 28 24.2	− 2.3	0.0	90 28 21.9	498	13.9	4.760 25
3	Herriman	90 36 01.3	− 1.7	0.0	90 35 59.6	498	13.2	4.889 86
3	Salt Creek	92 04 37.2	+ 9.1	− 1.1	92 04 45.2	497	11.9	4.212 11
5	Nephi Bench Mark	98 45 19.3	+34.3	−10.0	98 45 43.6	497	10.2	4.129 01
4	Lone Peak	90 27 25.5	− 1.7	0.0	90 27 23.8	497	13.2	4.900 61
3	Levan	92 00 33.3	+16.1	− 0.6	92 00 48.8	497	10.7	4.514 06
3	Cedar	93 39 48.5	+16.8	− 2.2	93 40 03.1	498	11.4	4.409 64
3	South Juab Base	93 40 26.9	+26.7	− 1.5	93 40 52.1	498	10.9	4.518 92
2	City Creek	91 20 40.4	+ 2.0	0.0	91 20 42.4	497	8.1	5.045 69
1	Springville Peak	90 29 14.7	− 2.6	0.0	90 29 12.1	496	16.1	4.710 70

Observations between 11 hours a. m. and 7 hours 30 minutes p. m., mostly before 1 hour p. m., except that all observations of Nephi Bench Mark, Levan, Cedar, and South Juab Base were made between 7 hours and 8 hours 30 minutes a. m.

Wasatch. July and August, 1890. Vertical Circle, No. 100. W. Eimbeck, P. A. Welker, O. B. French, and T. M. Vickers, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
14	Tushar	90 18 10·8	− 0·5	−0·3	90 18 19·6	512	15·8	5·055 35
14	Mount Nebo	90 10 19·1	− 0·2	−0·2	90 10 18·7	512	15·4	4·912 72
10	Scipio	90 38 06·1	− 4·5	0·0	90 38 01·6	512	16·1	4·857 12
11	Sanpete	90 08 48·6	+ 8·1	−0·2	90 08 56·5	512	15·7	4·464 04
14	Patmos Head	90 38 34·6	− 1·6	−0·1	90 38 32·9	512	15·7	5·029 77
13	Mount Ellen	90 26 43·3	− 0·4	+0·1	90 26 43·0	512	15·0	5·091 87
5	South Scipio	90 45 49·9	− 4·9	0·0	90 45 45·0	512	15·9	4·827 71
5	Mount Alice	90 03 11·6	− 6·8	+0·3	90 03 05·1	512	16·4	4·685 30
5	Mount Hilgard	90 03 08·3	− 6·3	+0·3	90 03 02·3	512	16·1	4·717 49
5	Monroe	90 16 29·3	− 4·5	+0·2	90 16 25·0	512	15·1	4·863 50
5	Mooseneah	90 14 52·6	−23·7	− 0·4	90 14 28·5	512	16·2	4·140 31
5	Lone Tree	90 32 03·7	− 5·4	0·0	90 31 58·3	512	15·7	4·784 60

Observations between 11 hours 20 minutes a. m. and 1 hour 30 minutes p. m., and between 4 hours 10 minutes and 6 hours p. m.

Mount Ellen. August, 1891. Vertical Circle, No. 100. P. A. Welker, and O. B. French, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
15	Wasatch	90 32 29·7	+ 1·3	+0·1	90 32 31·1	505	14·4	5·091 87
15	Mount Waas	90 29 00·3	+0·5	0·0	90 29 00·8	505	13·4	5·165 22
15	Tushar	90 29 40·1	+0·8	+0·1	90 29 41·0	505	13·9	5·157 43
17	Patmos Head	90 48 55·7	+0·8	0·0	90 48 56·5	505	13·6	5·202 17
7	Uncompahgre	91 00 23·2	+0·1	−0·1	91 00 23·2	505	13·0	5.468 52
4	Mount Hilgard	90 21 13·4	−2·4	+0·1	90 21 11·1	506	16·4	4·974 69
4	Mount Alice	90 20 52·1	−2·6	+0·1	90 20 49·6	506	16·6	4·950 49
5	Mooseneah	90 33 22·1	−1·9	+0·1	90 33 20·3	506	16·1	5·084 30

Observations between 11 hours 25 minutes a. m and 1 hour 15 minutes p. m., and between 4 hours 10 minutes and 6 hours 20 minutes p. m.

Patmos Head. September and October, 1890. Vertical Circle, No. 100. P. A. Welker and O. B. French, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
10	Wasatch	90 12 44·3	+2·0	+0·2	90 12 46·5	535	10·0	5·029 77
11	Mount Ellen	90 26 58·3	+0·8	+0·1	90 26 59·2	534	10·7	5·202 17
13	Mount Nebo	90 14 12·6	+1·3	+0·1	90 14 14·0	534	8·7	5·110 74
11	Mount Waas	90 15 35·4	+0·3	0·0	90 15 35·7	533	6·3	5·153 98
13	East Peak*	90 37 11·2	+1·0	−0·1	90 37 12·1	534	11·2	5·047 41
7	Sanpete	90 08 37·2	+4·0	+0·2	90 08 41·4	534	7·2	4·976 37
1	San Rafael Knob	90 43 45·5	−2·0	0·0	90 43 43·5	533	8·5	4·951 91
3	Valley Knob	91 49 28·5	+3·2	−0·2	91 49 31·5	528	−1·3	4·786 72

Observations between 11 hours 15 minutes a.m. and 1 hours 20 minutes p.m., and between 3 hours 30 minutes and 5 hours 50 minutes p.m.

* East Peak was not occupied for vertical measures, but it may be regarded as an eccentric station of Tavaputs and the above zenith distance at Patmos Head corrected accordingly. From the zenith distance of East Peak observed at

Mount Waas. July and August, 1893. Vertical Circle, No. 44. R. L. Faris, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
14	Patmos Head	90 52 16·8	+ 1·5	+0·1	90 52 18·4	490	12·8	5·153 98
13	Mount Ellen .	90 41 04·2	+ 1·4	0·0	90 41 05·6	490	12·8	5·165 22
16	Tavaputs	90 59 54·7	+ 1·7	0·0	90 59 56·4	490	12·4	5·052 08
10	Uncompahgre	90 26 38·8	+ 0·6	—0·1	90 26 39·3	491	12·9	5·211 99
8	Treasury Mountain	90 40 05·4	+ 0·6	0·0	90 40 06·0	490	11·6	5·284 11
8	Mesa	90 48 17·5	+ 1·5	0·0	90 48 19·0	490	12·4	4·998 26
3	Valley Knob	91 56 12·8	+ 2·0	—0·3	91 56 14·5	490	9·9	4·947 02
2	Azimuth Mark	89 49 15·2	—14·0	—0·8	89 49 00·4	489	9·8	4·057 16
1	Warners Ranch, Moab	95 24 09·0	+ 9·2	—1·3	95 24 16·9	489	7·6	4·431 10
1	Thompson's NE. water tank*	92 12 10·3	+27·0	—0·7	92 12 36·6	491	13·0	4·806 63
1	Thompson's SW. water tank*	92 12 09·9	+27·0	—0·7	92 12 36·2	491	13·4	4·805 81

Observations between noon and 1 hour and 20 minutes p.m., and between 4 hours 30 minutes and 7 hours p.m.

Tavaputs. September and October, 1891. Vertical Circle, No. 100. P. A. Welker and O. B. French, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
14	Uncompahgre .	90 22 20·8	+ 0·1	+ 0·1	90 22 21·0	555	10·2	5·324 39
19	Mount Waas	89 53 48·9	— 0·6	+ 0·3	89 53 48·6	556	10·3	5·052 08
13	Treasury Mountain	90 13 16·4	— 0·1	— 0·1	90 13 16·2	554	9·9	5·241 97
11	Patmos Head	90 17 01·1	+ 1·6	+ 0·1	90 17 02·8	555	11·4	5·052 27
11	East Peak	90 35 07·1	+62·6	—12·1	90 35 57·6	555	10·8	3·231 83
12	Grand Junction Standpipe	91 21 28·1	+95·5	— 0·1	91 23 03·5	555	10·7	4·810 39
6	Mesa	90 10 58·4	+ 1·2	0·0	90 10 59·6	559	10·2	5·002 90
2	Chiquita	90 21 16·0	+ 1·2	+ 0·1	90 21 17·3	559	10·1	4·882 22
5	Flat Top	90 36 32·1	+31·5	+ 0·7	90 37 04·3	556	9·3	4·153 02

Observations between 11 hours 45 minutes a. m. and 1 hour and 5 minutes p. m., and between 3 hours 30 minutes and 5 hours 10 minutes p. m.

Tavaputs and an assumed coefficient of refraction ($m = \cdot057$), Tavaputs was found to be 17·64 metres higher than East Peak. Patmos Head is approximately 1 253 metres nearer to East Peak than to Tavaputs. The zenith distance at Patmos Head of East Peak was first corrected for difference of height of East Peak and Tavaputs in the usual manner, and then for the difference of distance by the expression $\frac{d \cos \zeta}{s \sin 1''}$, in which d is the difference of distance, s the distance from Patmos Head to East Peak, and ζ the zenith distance at Tavaputs of Patmos Head. The resulting zenith distance of Tavaputs is—

		° ′ ″	″	″	° ′ ″	mm	°	
13	Tavaputs	90 37 12·1	—32·6	+11·5	90 36 51·0	534	11·2	5·052 27

*At about 7 hours a.m.

Mesa. August, 1893. Vertical Circle, No. 63. W. Eimbeck and C. C. Yates, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
6	Chiquita	90 46 48·0	−2·3	0·0	90 46 45·7	533	17·8	4·613 19
5	Mount Waas	89 59 07·7	−0·1	−0·1	89 59 07·5	533	15·9	4·998 26
6	Tavaputs	90 36 39·6	−0·6	0·0	90 36 39·0	534	18·1	5·002 90
4	Uncompahgre	89 46 18·3	−1·4	−0·2	89 46 16·7	533	16·2	5·046 32
5	Grand Junction Standpipe.	92 34 34·6	+157·0	−0·4	92 37 11·2	533	18·2	4·581 11

Observations between 11 hours 45 minutes a. m. and 2 hours p. m., and between 4 hours and 6 hours p. m.

Chiquita. May and June, 1895. Vertical Circle, No. 28. W. Eimbeck, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
9	Tavaputs	90 14 40·3	+0·1	0·0	90 14 40·4	556	10·7	4·882 22
8	Grand Junction Standpipe	93 30 00·3	+308·1	0·0	93 35 08·4	554	13·2	4·291 83
6	Mesa	89 32 35·9	−2·0	0·0	89 32 33·9	553	11·7	4·613 19

Observations between 11 hours 40 minutes a. m. and 1 hour 55 minutes p. m., and between 4 hours 15 minutes and 7 hours 30 minutes p. m.

Grand Junction Standpipe. May and June, 1895. Vertical Circle, No. 44. R. L. Faris, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
9	Chiquita	86 33 59·2	+21·8	−7·8	86 34 13·2	638	20·6	4·291 83
7	Mesa	87 40 40·8	+ 9·8	−3·1	87 40 47·5	642	21·2	4·581 11
6	Tavaputs	89 07 19·7	− 2·6	+1·3	89 07 18·4	641	16·9	4·810 39

Observations between 11 hours 50 minutes a. m. and 1 hour 10 minutes p. m., and between 5 hours 15 minutes and 6 hours 45 minutes p. m.

Gunnison. August and September, 1894, and October, 1895. Vertical Circle, No. 44. W. Eimbeck, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of △.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
5	Mount Ouray, 1894	88 29 59·8	−5·7	*0·0	88 29 54·1	...	19·9	
6	Mount Ouray, 1895	88 29 42·4	−0·1	0·0	88 29 42·3	576	10·5	
11	Mount Ouray, mean				88 29 47·7			4·796 48
6	Uncompahgre, 1895	88 38 38·1	+0·5	0·0	88 38 38·6	576	10·4	4·848 77

Observations in 1894 between 11 hours 14 minutes a. m. and 12 hours 20 minutes p. m., and between 5 hours 17 minutes and 6 hours 20 minutes p. m.; in 1895 between noon and 12 hours 45 minutes p. m., and between 4 hours and 5 hours 10 minutes p. m.

* The Vertical Circle occupied the stand of the heliotrope observed from Ouray and Uncompahgre. It is therefore merely necessary to correct log s so as to correspond to the distance from the Vertical Circle.

Uncompahgre. August and September, 1895. Vertical Circle, No. 28. R. L. Faris, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
12	Gunnison	91 55 03·9	+2·7	+0·7	91 55 07·3	456	7·0	4·848 77
15	Treasury Mountain	90 34 35·8	+1·8	0·0	90 34 37·6	455	6·0	5·038 70
15·5*	Mount Elbert	90 34 30·3	+1·2	−0·2	90 34 31·3	454	6·3	5·164 50
7	Mesa	91 07 32·4	+1·0	−0·1	91 07 33·3	455	5·1	5·046 32
14	Mount Waas	90 52 08·2	+1·5	+0·2	90 52 09·9	455	5·1	5·211 99
15·5*	Mount Ouray	90 30 54·7	+2·0	−0·3	90 30 56·4	454	5·9	5·061 12
10	Mount Ellen	91 20 47·2	+0·8	+0·3	91 20 48·3	455	4·9	5·468 52
8	Chiquita	91 17 05·8	+1·0	0·0	91 17 06·8	455	6·9	5·144 50
5	Tavaputs	91 18 23·4	+1·0	−0·1	91 18 24·5	456	7·6	5·324 39

Observations between 11 hours 30 minutes a. m. and 1 hour 10 minutes p. m., and between 4 hours 55 minutes and 6 hours 40 minutes p. m.

Mount Elbert. July, 1894. Vertical Circle, No. 28. P. A. Welker and J. Nelson, observers; P. A. Welker, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
11	Mount Ouray	90 25 27·0	−0·1	+0·1	90 25 27·0	454	7·0	4·900 39
10	Uncompahgre	90 36 26·0	+0·8	+0·2	90 36 27·0	455	6·9	5·164 50
10	Pikes Peak	90 33 04·5	+1·0	−0·1	90 33 05·4	454	6·5	5·097 79
10	Treasury Mountain	90 31 40·4	+3·8	0·0	90 31 44·2	454	6·7	4·761 40
8	Bison	90 45 21·0	−0·5	0·0	90 45 20·5	454	5·7	4·918 90

Observations between 11 hours a. m. and 1 hour 5 minutes p. m., and between 4 hours 20 minutes and 6 hours 50 minutes p. m.

Treasury Mountain. September, 1893. Vertical Circle, No. 44. R. L. Faris, observer; W. Eimbeck, chief of party. June and July, 1895. Vertical Circle, No. 44. R. L. Faris and W. H. Clay, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
14	Tavaputs, 1893	91 09 57·2	+1.7	0·0	91 09 58·9	467	5·3	5·241 97
14	Mount Waas, 1893	90 52 18·4	+1·8	0·0	90 52 20·2	467	5·2	5·284 11
12	Uncompahgre, 1893	90 18 16·2	+1·9	+0·1	90 18 18·2	466	4·5	5·038 70
11	Mount Ouray, 1893	90 18 59·8	+2·2	+0·1	90 19 02·1	467	5·1	
7	Mount Ouray, 1895	90 18 50·4	+3·4	+0·1	90 18 53·9	468	7·7	
18	Mount Ouray, mean				90 18 58·9			5·002 04
8	Mount Elbert, 1895	89 56 07·0	+4·7	+0·1	89 56 11·8	468	8·7	4·761 40

Observations in 1893 between noon and 1 hour p. m., and between 4 hours 45 minutes and 6 hours 10 minutes p. m.; in 1895 between 11 hours 50 minutes a. m. and 1 hour 20 p. m., and between 5 hours and 7 hours p. m.

Bison. July and August, 1894. Vertical Circle, No. 63. F. W. Perkins, F. L. Olmsted, jr., and P. L. Reed, observers; F. W. Perkins, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
8	Mount Ouray	90 12 06·3	−1·8	0·0	90 12 04·5	492	13·9	5·042 88
14	Pikes Peak	89 44 38·5	−4·9	0·0	89 44 33·6	493	13·0	4·771 60
8	Mount Elbert	89 54 49·4	−3·3	0·0	89 54 46·1	492	13·2	4·918 90
13	Divide	91 21 19·1	+0·1	0·0	91 21 19·2	492	13·0	4·940 23

Observations between 11 hours 35 minutes a. m. and 1 hour 5 minutes p. m.

* Micrometric differences September 16, reckoned as one-half day.

Mount Ouray. July and August, 1894. Vertical Circle, No. 44. R. L. Faris, observer; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
16	Mount Elbert	90 13 17.7	+ 0.1	− 0.2	90 13 17.6	461	8.9	4.900 39
18	Uncompahgre	90 24 49.8	0.0	+ 0.1	90 24 49.9	461	8.1	5.061 12
18	Pikes Peak	90 26 01.7	+ 1.0	− 0.1	90 26 02.6	461	9.1	5.052 21
18	Gunnison	92 00 03.5	+ 1.3	0.0	92 00 04.8	462	8.7	4.796 48
18	Treasury Mountain	90 29 41.5	+ 0.7	− 0.1	90 29 42.1	461	8.7	5.002 04
13	Bison	90 41 24.6	− 1.3	− 0.1	90 41 23.2	461	8.3	5.042 88
13	Plateau	91 36 43.0	+ 0.6	0.0	91 36 43.6	461	8.4	5.163 93
5	Marshall Pass railroad station	103 09 49.3	−60.1	0.0	*103 08 49.2	461	9.3	‡3.602 67
2	Marshall Pass summit	103 30 59.0	+15.9	0.0	†103 31 14.9	461	8.4	‡3.593 50
1	Azimuth signal	93 59 16.6	+36.1	0.0	93 59 52.7	462	11.8	‡3.954 35

Observations between 11 hours 30 minutes a. m. and 1 hour 5 minutes p. m., and between 4 hours 15 minutes and 7 hours 20 minutes p. m.

Pikes Peak. July and August, 1895. Vertical Circles, Nos. 28 and 44. J. Nelson, R. L. Faris, and W. H. Clay, observers; W. Eimbeck, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
11	Mount Ouray	90 28 52.8	− 0.6	+ 0.2	90 28 52.4	459	5.7	5.052 21
12	Mount Elbert	90 27 50.5	− 0.8	+ 0.3	90 27 50.0	460	6.2	5.097 79
10	Bison	90 44 05.0	+ 0.2	− 0.2	90 44 05.0	459	5.8	4.771 60
11	Divide	92 25 43.5	− 1.1	+ 1.2	92 25 43.6	460	6.7	4.721 59
9	Plateau	92 34 45.6	+18.7	−14.9	92 34 49.4	460	5.8	4.816 21
13	Big Springs	92 14 53.5	+17.5	−12.6	92 14 58.4	460	6.4	4.841 50

Observations between 11 hours 45 minutes a. m. and 1 hour 20 minutes p. m., and between 4 hours 30 minutes and 7 hours 5 minutes p. m.

Divide. July and August, 1895. Vertical Circle, No. 109. F. D. Granger and J. B. Boutelle, observers; F. D. Granger, chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
11	Big Springs	90 39 16.1	−1.6	0.0	90 39 14.5	578	22.9	4.623 06
12	Pikes Peak	87 59 24.9	+2.8	0.0	87 59 27.7	577	24.0	4.721 59
11	Bison	89 20 33.4	−1.4	0.0	89 20 32.0	576	23.2	4.940 23
3	Monté Rosa	88 49 23.1	−6.5	0.0	88 49 16.6	575	23.4	4.712 43

Observations between 11 hours 35 minutes a. m. and 1 hour p. m., and between 4 hours 35 minutes and 6 hours 30 minutes p. m.

Plateau. July and August, 1894, and September and October, 1895. Vertical Circle, No. 109. F. D. Granger, observer and chief of party.

Number of days.	Object observed.	Observed zenith distance.	Reduction to level of Δ.	Reduction for eccentricity.	Reduced ζ.	P.	T (c.)	Log s.
		° ′ ″	″	″	° ′ ″	mm.	°	
10	Pikes Peak	87 56 12.5	+9.2	0.0	87 56 21.7	616	30.4	4.816 21
13	Mount Ouray	89 33 20.8	−0.5	0.0	89 33 20.3	614	30.0	5.163 93
10	Big Springs	89 52 58.1	+0.7	0.0	89 52 58.8	615	27.5	4.679 47

Observations in 1894 between 11 hours 40 minutes a. m. and 1 hour 5 minutes p. m., and between 4 hours 45 minutes and 6 hours 55 minutes p. m.; in 1895 between 2 hours and 4 hours 40 minutes p. m.

* Reduced to top of tower. † Reduced to ground at foot of stake. ‡ Logarithmic distance from Vertical Circle.

2. COEFFICIENT OF REFRACTION.

In the development of the expression for the difference of height from reciprocal zenith distances there appears a term* depending upon the difference of the refraction at the two stations. This term is usually suppressed, in application, as insignificant. Assistant W. Eimbeck called attention to it when determining the heights of the Rocky Mountain stations and applied it in his field computation. If m_{I} and m_{II} are the coefficients of refraction at the upper and lower stations, respectively, we have the expression—

$$h_{\text{I}} - h_{\text{II}} = \left(s \tan \tfrac{1}{2} (\zeta_{\text{I}} - \zeta_{\text{II}}) + \frac{m_{\text{I}} - m_{\text{II}}}{2\rho} s^2 \right) \left(1 + \frac{h_{\text{I}} + h_{\text{II}}}{2\rho} + \frac{s^2}{12\rho^2} - \dots \right)$$

and the term $\frac{m_{\text{I}} - m_{\text{II}}}{2\rho} s^2$ will only disappear when the two stations are of the same elevation with like atmospheric conditions. For a great difference in elevation and a large distance the effect of this term evidently becomes a matter of importance. There is, however, a difficulty in obtaining a reliable value for $m_{\text{I}} - m_{\text{II}}$. To do this, we can only fall back upon the value of m as deduced from the nonsimultaneous reciprocal zenith distances of all the lines in this region, which are tabulated below in the order of decreasing average heights, $\tfrac{1}{2} (h_{\text{I}} + h_{\text{II}})$. The table also contains the temperature at the two stations and the weight of each value of the coefficient of refraction given by the expression $p = \frac{n_{\text{I}} n_{\text{II}}}{n_{\text{I}} + n_{\text{II}}} \cdot \frac{s^2}{10^{10}}$.

Table of resulting values of coefficient of refraction, arranged according to the mean height of the two stations.

Stations.	Temperature. t_{I}.	t_{II}.	Mean.	Height (approx.). h_{I}.	h_{II}.	Mean.	m.	p.
	°	°	°	Metres.				
Mount Elbert to Uncompahgre	6·9	6·3	6·6	4 398	4 359	4 378	·049 9	13·0
Mount Elbert to Pikes Peak	6·5	6·2	6·4	4 398	4 300	4 349	·048 4	8·6
Mount Elbert to Mount Ouray	7·0	8·9	8·0	4 398	4 257	4 328	·049 1	4·1
Uncompahgre to Mount Ouray	5·9	8·1	7·0	4 359	4 257	4 308	·050 1	11·0
Pikes Peak to Mount Ouray	5·7	9·1	7·4	4 300	4 257	4 278	·047 9	8·7
Mount Elbert to Treasury Mountain	6·7	8·7	7·7	4 398	4 100	4 249	·050 6	1·5
Uncompahgre to Treasury Mountain	6·0	4·5	5·2	4 359	4 100	4 230	·052 0	8·0
Mount Ouray to Treasury Mountain	8·7	6·1	7·4	4 257	4 100	4 178	·050 7	9·1
Mount Elbert to Bison	5·7	13·2	9·4	4 398	3 788	4 093	·051 0	2·8
Uncompahgre to Mount Waas	5·1	12·9	9·0	4 359	3 753	4 056	·050 8	15·5
Pikes Peak to Bison	5·8	13·0	9·4	4 300	3 788	4 044	·050 8	2·0
Mount Ouray to Bison	8·3	13·9	11·1	4 257	3 788	4 022	·051 4	6·0
Uncompahgre to Mount Ellen	4·9	13·0	9·0	4 359	3 498	3 928	·054 0	35·6
Treasury Mountain to Mount Waas	5·2	11·6	8·4	4 100	3 753	3 926	·053 8	18·8
Wheeler Peak to Tushar	−6·6	9·3	1·4	3 967	3 700	3 834	·058 9	11·7

*T. W. Wright's Treatise on the Adjustment of Observations, New York, 1884, p. 387. (k stands there for $2m$ in our notation.)

Table of resulting values of coefficient of refraction, arranged according to the mean height of the two stations—Continued.

Stations.	Temperature.			Height (approx.).			m.	p.
	t_{I}	t_{II}	Mean.	h_{I}.	h_{II}.	Mean.		
	°	°	°	Metres.				
Wheeler Peak to Ibepah	−5·6	13·6	4·0	3 967	3 684	3 826	·059 1	5·3
Wheeler Peak to Mount Nebo	−5·4	11·0	2·8	3 967	3 620	3 794	·059 3	9·7
Wheeler Peak to White Pine	−5·4	0·7	−2·4	3 967	3 426	3 696	·066 0	7·5
Uncompahgre to Mesa	5·1	16·2	10·6	4 359	3 039	3 699	·051 8	3·2
Tushar to Ibepah	11·6	11·1	11·4	3 700	3 684	3 692	·054 4	14·9
Tushar to Mount Nebo	10·1	13·6	11·8	3 700	3 620	3 660	·053 8	15·2
Ibepah to Mount Nebo	12·0	13·7	12·8	3 684	3 620	3 652	·054 8	15·3
Mount Conness to Mount Grant	11·7(?)	4·5	8·1	3 835	3 427	3 631	·050 3	2·8
Mount Waas to Mount Ellen	12·8	13·4	13·1	3 753	3 498	3 626	·055 1	14·9
Wheeler Peak to Diamond Peak	−5·8	13·6	3·9	3 967	3 242	3 604	·061 0	12·4
Tushar to Mount Ellen	8·4	13·9	11·2	3 700	3 498	3 599	·053 6	13·1
Tushar to Wasatch	9·4	15·8	12·6	3 700	3 394	3 547	·052 3	8·3
Ibepah to Deseret	12·0	12·1	12·0	3 684	3 360	3 522	·056 2	14·4
Uncompahgre to Tavaputs	7·6	10·2	8·9	4 359	2 667	3 513	·057 7	16·4
Toiyabe Dome to Mount Grant	9·4	3·8	6·6	3 595	3 427	3 511	·060 7	11·0
Toiyabe Dome to White Pine	10·0	−0·1	5·0	3 595	3 426	3 510	·061 8	17·1
Mount Nebo to Wasatch	13·5	15·4	14·4	3 620	3 394	3 507	·051 3	4·5
Mount Nebo to Deseret	13·4	11·9	12·6	3 620	3 360	3 490	·055 4	7·7
Ibepah to Pilot Peak	10·4	17·8	14·1	3 684	3 270	3 477	·054 5	15·9
Ibepah to Diamond Peak	7·6	13·6	10·6	3 684	3 242	3 463	·054 5	16·2
Mount Nebo to Pilot Peak	14·3	18·9	16·6	3 620	3 270	3 445	·054 7	22·2
Mount Ellen to Wasatch	14·4	15·0	14·7	3 498	3 394	3 446	·056 3	10·6
Toiyabe Dome to Diamond Peak	11·8	9·8	10·8	3 595	3 242	3 418	·053 7	14·7
Mount Waas to Mesa	12·4	15·9	14·2	3 753	3 039	3 396	·057 9	3·0
Treasury Mountain to Tavaputs	5·3	9·9	7·6	4 100	2 667	3 384	·057 2	20·6
Mount Waas to Patmos Head	12·8	6·3	9·6	3 753	2 992	3 372	·058 6	12·5
Toiyabe Dome to Mount Callahan	9·6	16·9	13·2	3 595	3 117	3 356	·048 9	6·7
Uncompaghre to Gunnison	7·0	10·4	8·7	4 359	2 341	3 350	·056 9	2·0
White Pine to Diamond Peak	1·1	10·9	6·0	3 426	3 242	3 334	·061 1	12·6
Tushar to Scipio	9·2	12·4	10·8	3 700	2 960	3 330	·054 6	7·5
Wheeler Peak to Pioche	−6·2	20·2	7·0	3 967	2 677	3 322	·060 1	6·1
Deseret to Pilot Peak	12·4	18·1	15·2	3 360	3 270	3 315	·056 3	24·4
Mount Nebo to Patmos Head	13·0	8·7	10·8	3 620	2 992	3 306	·054 1	9·4
Mount Ouray to Gunnison	8·7	14·8	11·8	4 257	2 341	3 299	·056 7	2·7
Ibepah to Ogden Peak	12·4	12·3	12·4	3 684	2 913	3 298	·056 5	11·8
Mount Grant to Round Top	7·4	12·7	10·0	3 427	3 166	3 296	·056 8	7·3
Mount Nebo to Scipio	12·8	11·9	12·4	3 620	2 960	3 290	·057 3	2·3
Pikes Peak to Divide	6·7	24·0	15·4	4 300	2 259	3 280	·056 2	1·6
Mount Nebo to Ogden Peak	14·2	13·0	13·6	3 620	2 913	3 266	·055 5	15·4
Mount Ellen to Patmos Head	13·6	10·7	12·2	3 498	2 992	3 245	·058 9	16·9
Mount Waas to Tavaputs	12·4	10·3	11·4	3 753	2 667	3 210	·058 9	11·0

Table of resulting values of coefficient of refraction, arranged according to the mean height of the two stations—Continued.

Stations.	Temperature. t_{I}.	t_{II}.	Mean.	Height (approx.). h_{I}.	h_{II}.	Mean.	m.	p.
	°	°	°	Metres.				
Wasatch to Patmos Head	15·7	10·0	12·8	3 394	2 992	3 193	·055 2	6·7
Tushar to Pioche	8·7	20·1	14·4	3 700	2 677	3 188	·054 2	11·5
Toiyabe Dome to Lone Mountain	12·5	1·7	7·1	3 595	2 767	3 181	·060 9	5·3
Diamond Peak to Mount Callahan	13·7	16·5	15·1	3 242	3 117	3 180	·052 0	6·5
Wasatch to Scipio	16·1	11·8	14·0	3 394	2 960	3 177	·053 3	3·0
Deseret to Scipio	11·9	11·8	11·8	3 360	2 960	3 160	·056 0	5·1
Toiyabe Dome to Carson Sink	10·0	20·2	15·1	3 595	2 685	3 140	·054 1	7·6
Deseret to Ogden Peak	12·6	15·0	13·8	3 360	2 913	3 136	·057 3	10·1
Pikes Peak to Big Springs	6·4	27·2	16·8	4 300	1 903	3 102	·059 6	2·9
Mount Grant to Lone Mountain	5·0	2·0	3·5	3 427	2 767	3 097	·066 0	10·5
White Pine to Lone Mountain	—0·4	2·4	1·0	3 426	2 767	3 096	·070 1	19·7
Pilot Peak to Ogden Peak	18·0	12·0	15·0	3 270	2 913	3 092	·058 2	41·2
Mount Grant to Mount Como	7·4	18·3	12·8	3 427	2 750	3 088	·056 1	3·5
Mount Grant to Carson Sink	4·9	21·2	13·0	3 427	2 685	3 056	·060 4	8·2
White Pine to Pioche	0·2	19·0	9·6	3 426	2 677	3 052	·061 6	9·9
Bison to Divide	13·0	23·2	18·1	3 788	2 259	3 024	·053 9	4·5
Round Top to Mount Lola	12·1	12·2	12·2	3 166	2 787	2 976	·058 5	5·8
Pikes Peak to Plateau	5·8	30·4	18·1	4 300	1 644	2 972	·058 7	2·0
Round Top to Mount Como	12·7	18·1	15·4	3 166	2 750	2 958	·054 7	3·0
Mount Ouray to Plateau	8·4	30·0	19·2	4 257	1 644	2 950	·053 7	13·8
Mount Callahan to Carson Sink	17·6	20·8	19·2	3 117	2 685	2 901	·053 3	7·2
Mesa to Tavaputs	18·1	10·2	14·2	3 039	2 667	2 853	·061 3	3·0
Patmos Head to Tavaputs	11·2	11·4	11·3	2 992	2 667	2 830	·056 2	7·6
Mesa to Chiquita	17·8	11·7	14·8	3 039	2 595	2 817	·062 6	0·5
Mount Lola to Mount Como	12·5	17·9	15·2	2 787	2 750	2 768	·055 8	4·6
Mount Como to Carson Sink	17·0	20·0	18·5	2 750	2 685	2 718	·056 0	8·4
Deseret to Antelope	12·6	12·7	12·6	3 360	2 005	2 682	·063 1	3·8
Deseret to Promontory	13·2	25·9	19·6	3 360	2 004	2 682	·058 7	7·2
Mount Lola to Pah-Rah	12·6	7·7	10·2	2 787	2 510	2 648	·063 7	3·1
Pilot Peak to Antelope	16·2	9·7	13·0	3 270	2 005	2 638	·063 7	13·4
Pilot Peak to Promontory	18·1	27·6	22·8	3 270	2 004	2 637	·057 3	14·1
Tavaputs to Chiquita	10·1	10·7	10·4	2 667	2 595	2 631	·063 4	1·0
Mount Como to Pah-Rah	16·9	11·1	14·0	2 750	2 510	2 630	·057 3	3·4
Carson Sink to Pah-Rah	20·5	8·8	14·6	2 685	2 510	2 598	·063 9	6·5
Ogden Peak to Antelope	15·5	17·5	16·5	2 913	2 005	2 459	·063 2	1·6
Ogden Peak to Promontory	18·2	25·5	21·8	2 913	2 004	2 458	·065 9	0·9
Ogden Peak to City Creek	12·8	14·1	13·4	2 913	1 870	2 392	·056 7	0·7
Deseret to Waddoup	13·0	23·4	18·2	3 360	1 297	2 328	·062 8	5·1
Mesa to Grand Junction Standpipe	18·2	21·2	19·7	3 039	1 394	2 216	·062 4	0·4
Ogden Peak to United States Engineers' Observatory	13·8	23·6	18·7	2 913	1 326	2 120	·066 9	0·04

Table of resulting values of coefficient of refraction, arranged according to the mean height of the two stations—Completed.

Stations.	Temperature. t_{I}.	t_{II}.	Mean.	Height (approx.). h_{I}.	h_{II}.	Mean.	m.	p.
	°	°	°	Metres.				
Ogden Peak to Waddoup	16·9	25·3	21·1	2 913	1 297	2 105	·058 2	0·6
Ogden Peak to Salt Lake NW. Base	16·9	31·7	24·3	2 913	1 284	2 098	·065 8	0·2
Ogden Peak to Salt Lake SE. Base	16·7	28·6	22·6	2 913	1 278	2 095	·062 8	0·2
Divide to Big Springs	22·9	25·0	24·0	2 259	1 903	2 081	·052 0	1·0
Tavaputs to Grand Junction Standpipe	10·7	16·9	13·8	2 667	1 394	2 030	·064 8	1·7
Antelope to Promontory	17·9	25·1	21·5	2 005	2 004	2 004	·066 5	1·9
Chiquita to Grand Junction Standpipe	13·2	20·6	16·9	2 595	1 394	1 994	·057 5	0·2
Antelope to City Creek	12·1	14·1	13·1	2 005	1 870	1 938	·071 9	0·3
Big Springs to Plateau	25·2	27·5	26·4	1 903	1 644	1 774	·052 4	1·2
Antelope to Waddoup	18·0	25·5	21·8	2 005	1 297	1 651	·075 1	1·0
Promontory to Waddoup	25·4	23·7	24·6	2 004	1 297	1 650	·069 4	4·6
Antelope to Salt Lake NW. Base	25·9	32·4	29·2	2 005	1 284	1 644	·061 2	0·1
Promontory to Salt Lake NW. Base	24·8	31·7	28·2	2 004	1 284	1 644	·068 1	0·4
Antelope to Salt Lake SE. Base	26·4	27·6	27·0	2 005	1 278	1 642	·064 0	0·1
Waddoup to Salt Lake SE. Base	31·1	30·0	30·6	1 297	1 278	1 288	·049 3	0·1
Salt Lake NW. Base to SE. Base	33·9	27·4	30·6	1 284	1 278	1 281	·046 2	0·04

An inspection of this table shows a steady increase in the coefficient of refraction as the height decreases, except where the temperature is abnormally high or low, in which case the value of m is correspondingly low or high. It was therefore decided to try to derive an expression for the coefficient of refraction of the form—

$$m = m_0 + (t - t_0)x + (h - h_0)y$$

At first 8 groups of 10 values each were formed, and the weighted mean values of temperature, height, and coefficient of refraction were found for each group. An expression of the above form was found which fitted very closely these mean values, but when applied to the individual values of m the agreement was not satisfactory, nor did the use of it in the height computations produce a satisfactory closure of the height triangles. This was ascribed partly to the fact that the variations in temperature are largely concealed by taking the group means and partly to a regional difference in topography and local conditions between the eastern and western parts of the triangulation.

It was therefore concluded to use the individual values of m, disregarding the computed weights, and to derive two expressions, one for the eastern part of the triangulation from Pikes Peak to Mount Nebo and another for the remaining western part. Thirty values are included in the first part and 46 in the second; several values evidently abnormal as well as those derived from short lines being rejected. The mean values for the eastern part are $t_0 = 9°{\cdot}9\,c$, $h_0 = 37{\cdot}7$ hectometres, $m_0 = {\cdot}053\,4$, and the resulting observation equations of the form $(t - t_0)x + (h - h_0)y = m - m_0$ are tabulated below. For convenience of computing, $(h - h_0)$ is given in hectometres and $(m - m_0)$ in units of the fourth place of decimals.

Station.	$t-t_0$ °	$h-h_0$	$m-m_0$	Computed.	$O-C$
Mount Elbert to Uncompahgre	−3·3	+6·1	−35	−41	+ 6
Mount Elbert to Pikes Peak	−3·5	+5·8	−50	−38	−12
Mount Elbert to Mount Ouray	−1·9	+5·6	−43	−42	− 1
Uncompahgre to Mount Ouray	−2·9	+5·4	−33	−37	+ 4
Pikes Peak to Mount Ouray	−2·5	+5·1	−55	−35	−20
Mount Elbert to Treasury Mountain	−2·2	+4·8	−28	−34	+ 6
Uncompahgre to Treasury Mountain	−4·7	+4·6	−14	−23	+ 9
Mount Ouray to Treasury Mountain	−2·5	+4·1	−27	−27	0
Mount Elbert to Bison	−0·5	+3·2	−24	−26	+ 2
Uncompahgre to Mount Waas	−0·9	+2·9	−26	−22	− 4
Pikes Peak to Bison	−0·5	+2·7	−26	−22	− 4
Mount Ouray to Bison	+1·2	+2·5	−20	−26	+ 6
Uncompahgre to Mount Ellen	−0·9	+1·6	+ 6	−11	+17
Treasury Mountain to Mount Waas	−1·5	+1·6	+ 4	− 9	+13
Uncompahgre to Mesa	+0·7	−0·7	−16	+ 4	−20
Mount Waas to Mount Ellen	+3·2	−1·4	+17	+ 1	+16
Tushar to Mount Ellen	+1·3	−1·7	+ 2	+10	− 8
Tushar to Wasatch	+2·7	−2·2	−11	+ 9	−20
Uncompahgre to Tavaputs	−1·0	−2·6	+43	+26	+17
Mount Nebo to Wasatch	+4·5	−2·6	−21	+ 6	−27
Mount Ellen to Wasatch	+4·8	−3·2	+29	+11	+18
Mount Waas to Mesa	+4·3	−3·7	+45	+17	+28
Treasury Mountain to Tavaputs	2·3	−3·9	+38	+42	− 4
Mount Waas to Patmos Head	0·3	−4·0	+52	+36	+16
Uncompahgre to Gunnison	−1·2	−4·2	+35	+41	− 6
Mount Nebo to Patmos Head	+0·9	−4·6	+ 7	+37	−30
Mount Ouray to Gunnison	+1·9	−4·7	+33	+34	− 1
Mount Ellen to Patmos Head	+2·3	−5·3	+55	+38	+17
Mount Waas to Tavaputs	+1·5	−5·6	+55	+43	+12
Wasatch to Patmos Head	+2·9	−5·8	+18	+40	−22

The resulting normal equations are—

$$\left.\begin{array}{r} 190{\cdot}08\,x - 217{\cdot}07\,y = +1\ 209{\cdot}8 \\ -217{\cdot}07\,x + 488{\cdot}52\,y = -3\ 471{\cdot}6 \end{array}\right\} \text{ from which } \left\{\begin{array}{l} x = -3{\cdot}6 \\ y = -8{\cdot}7 \end{array}\right.$$

and the expression for the coefficient of refraction is—

$$m = {\cdot}053\ 4 - {\cdot}000\ 36\,(t - 9^\circ{\cdot}9) - {\cdot}000\ 87\,(h - 37{\cdot}7)$$

In the height computations we need only the difference of refraction at the two stations, which may be found directly from the expression—

$$\frac{m_{\rm I} - m_{\rm II}}{2} = {\cdot}000\ 18\,(t_{\rm II} - t_{\rm I}) - {\cdot}000\ 44\,(h_{\rm I} - h_{\rm II})$$

in which $m_{\rm I}$ $t_{\rm I}$ and $h_{\rm I}$ refer to the upper station and $m_{\rm II}$ $t_{\rm II}$ and $h_{\rm II}$ to the lower, and the unit of height is a hectometre.

For the Western part the mean values are $t_0 = 11°·2$ C. $h_0 = 32·5$ hectometres and $m_0 = ·057\,8$. The resulting observation equations are tabulated below:

Stations.	$t-t_0$ °	$h-h_0$	$m-m_0$	Computed.	$O-C$.
Wheeler Peak to Tushar	−9·8	+5·8	+11	+27	−16
Wheeler Peak to Ibepah	−7·2	+5·8	+13	+6	+7
Wheeler Peak to Mount Nebo	−8·4	+5·4	+15	+19	−4
Wheeler Peak to White Pine	−13·6	+4·5	+82	+69	+13
Tushar to Ibepah	+0·2	+4·4	−34	−42	+8
Tushar to Mount Nebo	+0·6	+4·1	−40	−42	+2
Ibepah to Mount Nebo	+1·6	+4·0	−30	−49	+19
Wheeler Peak to Diamond Peak	−7·3	+3·5	+32	+27	+5
Ibepah to Deseret	+0·8	+2·7	−16	−31	+15
Toiyabe Dome to Mount Grant	−4·6	+2·6	+29	+14	+15
Toiyabe Dome to White Pine	−6·2	+2·6	+40	+27	+13
Mount Nebo to Deseret	+1·4	+2·4	−24	−33	+9
Ibepah to Pilot Peak	+2·9	+2·3	−33	−44	+11
Ibepah to Diamond Peak	−0·6	+2·1	−33	−14	−19
Mount Nebo to Pilot Peak	+5·4	+1·9	−31	−61	+30
Toiyabe Dome to Diamond Peak	−0·4	+1·7	−41	−12	−29
White Pine to Diamond Peak	−5·2	+0·8	+33	+35	−2
Tushar to Scipio	+0·4	+0·8	−32	−4	−28
Wheeler Peak to Pioche	−4·2	+0·7	+23	+28	−5
Deseret to Pilot Peak	+4·0	+0·7	−15	−39	+24
Mount Grant to Round Top	−1·2	+0·5	−10	+5	−15
Ibepah to Ogden Peak	+1·2	+0·5	−13	−14	+1
Mount Nebo to Scipio	+1·2	+0·4	−5	−13	+8
Mount Nebo to Ogden Peak	+2·4	+0·2	−23	−21	−2
Tushar to Pioche	+3·2	−0·6	−36	−20	−16
Toiyabe Dome to Lone Mountain	−4·1	−0·7	+31	+40	−9
Diamond Peak to Mount Callahan	+3·9	−0·7	−58	−25	−33
Wasatch to Scipio	+2·8	−0·7	−45	−16	−29
Deseret to Scipio	+0·6	−0·9	−18	+3	−21
Toiyabe Dome to Carson Sink	+3·9	−1·1	−37	−22	−15
Deseret to Ogden Peak	+2·6	−1·1	−5	−11	+6
Mount Grant to Lone Mountain	−7·7	−1·5	+82	+76	+6
White Pine to Lone Mountain	−10·2	−1·5	+123	+96	+27
Pilot Peak to Ogden Peak	+3·8	−1·6	+4	−16	+20
Mount Grant to Mount Como	+1·6	−1·6	−17	+2	−19
Mount Grant to Carson Sink	+1·8	−1·9	+26	+3	+23
White Pine to Pioche	−1·6	−2·0	+38	+31	+7
Round Top to Mount Lola	+1·0	−2·7	+7	+16	−9
Round Top to Mount Como	+4·2	−2·9	−31	−8	−23
Mount Callahan to Carson Sink	+8·0	−3·5	−45	−33	−12
Mount Lola to Mount Como	+4·0	−4·8	−20	+11	−31

Stations.	$t-t_0$	$h-h_0$	$m-m_0$	Computed.	$O-C$.
	°				
Mount Como to Carson Sink	+ 7·3	−5·3	− 18	−11	− 7
Deseret to Antelope	+ 1·4	−5·7	+ 53	+41	+12
Deseret to Promontory	+ 8·4	−5·7	+ 9	−16	+25
Pilot Peak to Antelope	+ 1·8	−6·1	+ 59	+41	+18
Pilot Peak to Promontory	+11·6	−6·1	− 5	−38	+33

The resulting normal equations are—

$$\left.\begin{array}{r} 1\,251{\cdot}67\,x - 464{\cdot}01\,y = -5\,961{\cdot}1 \\ -464{\cdot}01\,x + 467{\cdot}61\,y = -479{\cdot}9 \end{array}\right\} \text{from which} \left\{\begin{array}{l} x = -8{\cdot}1 \\ y = -9{\cdot}1 \end{array}\right.$$

and the expression for the coefficient of refraction is—

$$m = {\cdot}057\,8 - {\cdot}000\,81\,(t - 11^\circ{\cdot}2) - {\cdot}000\,91\,(h - 32{\cdot}5)$$

For the difference of refraction at two stations we have—

$$\frac{m_{\text{I}} - m_{\text{II}}}{2} = {\cdot}000\,40\,(t_{\text{II}} - t_{\text{I}}) - {\cdot}000\,45\,(h_{\text{I}} - h_{\text{II}})$$

The next to the last column in the preceding tables contains the computed values of $(m - m_0)$ and the residuals are given in the last column. While some of the residuals are large, yet in general the agreement is quite good, and the two expressions for $m_{\text{I}} - m_{\text{II}}$ have been adopted for use in the computation of differences of height.

The differences of height between the stations were computed by the formula as given above and inclusive of the term $(m_{\text{I}} - m_{\text{II}}) \dfrac{s^2}{2\rho}$.

3. ADJUSTMENT OF HEIGHTS.

The adjustment of heights has been divided into two parts, the first including the principal triangulation stations between Round Top and Pikes Peak, as shown on the preceding sketch, and the second the stations in the vicinity of the Salt Lake Base.* The heights of the following stations have been fixed by previous adjustments:

	m.
Round Top	3 165·6
Mount Lola	2 786·8
Pikes Peak	4 300·2
Divide	2 259·2
Plateau	1 644·0

* See subsketch farther on.

The approximate heights of the 28 intermediate stations are—

	m.		m.
Mount Como	2 749 $+x_1$	Deseret	3 368 $+x_{15}$
Pah-Rah	2 514 $+x_2$	Scipio	2 967 $+x_{16}$
Mount Grant	3 430 $+x_3$	Wasatch	3 398 $+x_{17}$
Carson Sink	2 684 $+x_4$	Patmos Head	3 003 $+x_{18}$
Toiyabe Dome	3 594 $+x_5$	Mount Ellen	3 501 $+x_{19}$
Lone Mountain	2 779 $+x_6$	Mount Waas	3 754 $+x_{20}$
Mount Callahan	3 116 $+x_7$	Tavaputs	2 680 $+x_{21}$
Diamond Peak	3 248 $+x_8$	Mesa	3 050 $+x_{22}$
White Pine	3 440 $+x_9$	Uncompahgre	4 355 $+x_{23}$
Wheeler Peak	3 982 $+x_{10}$	Gunnison	2 343 $+x_{24}$
Pioche	2 682 $+x_{11}$	Treasury Mountain	4 098 $+x_{25}$
Ibepah	3 692 $+x_{12}$	Mount Ouray	4 254 $+x_{26}$
Tushar	3 703 $+x_{13}$	Mount Elbert	4 396 $+x_{27}$
Mount Nebo	3 623 $+x_{14}$	Bison	3 786 $+x_{28}$

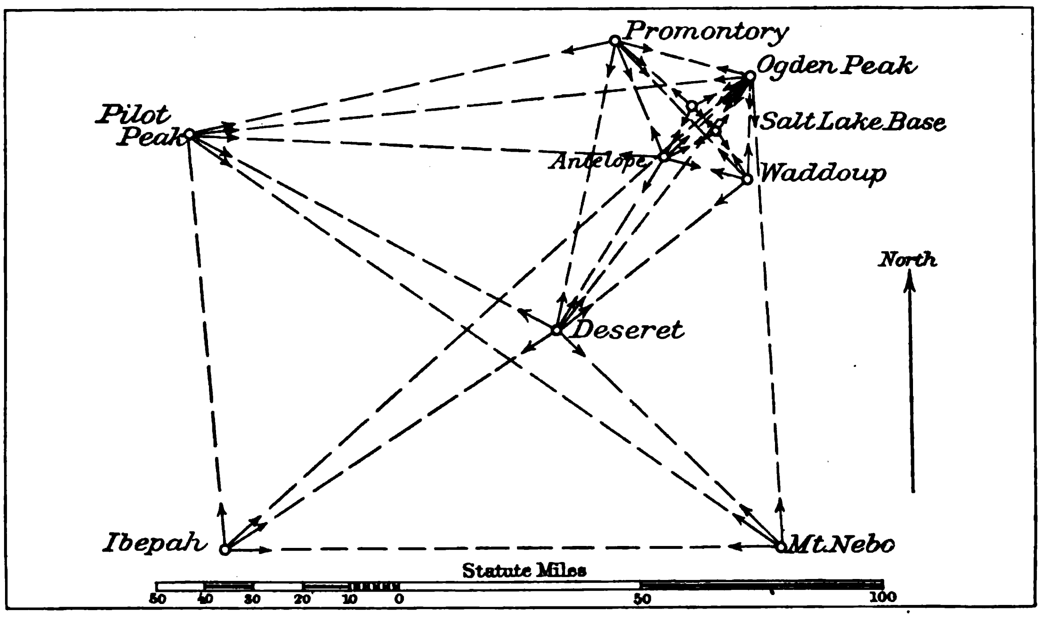
The computed differences of height with their weights and the corresponding observation equations are given in the following table. The very long line Uncompahgre to Mount Ellen is rejected:

Stations.	Δh.	p.	Observation equations.	Adjusted Δh.	Residuals.
	m.			m.	m.
Round Top to Mount Lola	376·6	8·4		(378·8)	
Round Top to Mount Como	417·0	22·2	$0=+0.4+x_1$	417·4	−0·4
Mount Lola to Pah-Rah	275·5	5·5	$0=+2.7+x_2$	273·3	+2·2
Mount Lola to Mount Como	40·4	7·2	$0=+2.6+x_1$	38·6	+1·8
Mount Como to Pah-Rah	232·1	6·3	$0=+2.9+x_1-x_2$	234·7	+2·6
Mount Grant to Round Top	263·1	5·9	$0=+1.3+x_3$	262·4	−0·7
Carson Sink to Pah-Rah	168·2	4·6	$0=+1.8-x_2+x_4$	167·3	−0·9
Mount Grant to Mount Como	679·1	9·7	$0=+1.9-x_1+x_3$	679·8	+0·7
Mount Grant to Carson Sink	741·5	3·6	$0=+4.5+x_3-x_4$	747·2	+5·7
Mount Grant to Lone Mountain	656·0	3·8	$0=+5.0-x_3+x_6$	651·2	+4·8
Mount Como to Carson Sink	70·6	3·6	$0=+5.6-x_1+x_4$	67·3	+3·3
Toiyabe Dome to Mount Grant	161·1	4·0	$0=+2.9-x_3+x_5$	162·4	+1·3
Toiyabe Dome to Carson Sink	911·4	4·7	$0=+1.4+x_4-x_5$	909·5	+1·9
Toiyabe Dome to Lone Mountain	813·4	7·9	$0=+1.6+x_5-x_6$	813·5	+0·1
Toiyabe Dome to Mount Callahan	479·6	5·8	$0=+1.6-x_5+x_7$	479·0	+0·6
Toiyabe Dome to Diamond Peak	345·4	2·4	$0=+0.6+x_5-x_8$	349·1	+3·7
Toiyabe Dome to White Pine	154·6	2·0	$0=+0.6-x_5+x_9$	153·2	+1·4
Mount Callahan to Carson Sink	431·3	4·7	$0=+0.7-x_4+x_7$	430·5	−0·8
Diamond Peak to Mount Callahan	130·0	7·0	$0=+2.0-x_7+x_8$	129·9	−0·1
White Pine to Diamond Peak	195·0	3·0	$0=+3.0+x_8-x_9$	195·8	−0·8
White Pine to Lone Mountain	651·7	2·0	$0=+9.3-x_6+x_9$	660·3	+8·6
White Pine to Pioche	757·4	3·2	$0=+0.6+x_9-x_{11}$	758·1	+0·7
Wheeler Peak to White Pine	534·5	2·9	$0=+7.5-x_9+x_{10}$	543·0	+8·5
Wheeler Peak to Diamond Peak	737·8	2·7	$0=+3.8+x_8-x_{10}$	738·9	−1·1

Stations.	Δh.	p.	Observation equations.	Adjusted Δh.	Residuals.
	m.			*m.*	*m.*
Wheeler Peak to Ibepah	294·6	5·4	$0=+4·6-x_{10}+x_{12}$	291·6	+3·0
Wheeler Peak to Pioche	1 301·0	3·7	$0=+1·0-x_{10}+x_{11}$	1 301·1	−0·1
Wheeler Peak to Mount Nebo	365·2	0·3	$0=+6·2-x_{10}+x_{14}$	357·1	+8·1
Wheeler Peak to Tushar	286·0	1·2	$0=+7·0-x_{10}+x_{13}$	278·2	+7·8
Ibepah to Diamond Peak	453·9	2·2	$0=+9·9+x_{8}-x_{12}$	447·2	+6·7
Ibepah to Mount Nebo	64·9	1·3	$0=+4·1+x_{12}-x_{14}$	65·5	+0·6
Tushar to Ibepah	9·8	0·9	$0=+1·2-x_{12}+x_{13}$	13·4	+3·6
Tushar to Pioche	1 024·0	2·2	$0=+3·0+x_{11}-x_{13}$	1 022·9	+1·1
Ibepah to Deseret	321·2	4·9	$0=+2·8+x_{12}-x_{15}$	321·4	+0·2
Mount Nebo to Deseret	255·6	6·9	$0=+0·6-x_{14}+x_{15}$	256·0	−0·4
Deseret to Scipio	398·4	2·2	$0=+2·6+x_{15}-x_{16}$	400·1	+1·7
Mount Nebo to Scipio	656·6	18·1	$0=+0·6-x_{14}+x_{16}$	656·1	+0·5
Wasatch to Scipio	430·8	11·3	$0=+0·2-x_{16}+x_{17}$	430·6	−0·2
Tushar to Scipio	733·5	5·2	$0=+2·5+x_{13}-x_{16}$	735·0	+1·5
Tushar to Mount Nebo	82·0	2·1	$0=+2·0-x_{13}+x_{14}$	78·9	+3·1
Tushar to Wasatch	305·6	5·0	$0=+0·6-x_{13}+x_{17}$	304·3	+1·3
Tushar to Mount Ellen	203·0	3·1	$0=+1·0-x_{13}+x_{19}$	201·4	+1·6
Mount Nebo to Wasatch	225·7	10·1	$0=+0·7-x_{14}+x_{17}$	225·4	+0·3
Mount Nebo to Patmos Head	619·6	3·4	$0=+0·4+x_{14}-x_{18}$	620·0	+0·4
Wasatch to Patmos Head	396·6	5·1	$0=+1·6-x_{17}+x_{18}$	394·6	+2·0
Mount Ellen to Wasatch	103·6	4·6	$0=+0·6+x_{17}-x_{19}$	102·9	+0·7
Mount Ellen to Patmos Head	497·8	2·6	$0=+0·2-x_{18}+x_{19}$	497·5	−0·3
Mount Waas to Mount Ellen	253·8	3·3	$0=+0·8+x_{19}-x_{20}$	254·1	−0·3
Mount Waas to Patmos Head	747·3	3·0	$0=+3·7-x_{18}+x_{20}$	751·6	+4·3
Mount Waas to Tavaputs	1 074·6	6·8	$0=+0·6-x_{20}+x_{21}$	1 074·5	+0·1
Patmos Head to Tavaputs	322·2	4·7	$0=+0·8+x_{18}-x_{21}$	322·9	+0·7
Mount Waas to Mesa	709·1	3·1	$0=+5·1-x_{20}+x_{22}$	706·7	+2·4
Mesa to Tavaputs	371·1	3·0	$0=+1·1+x_{21}-x_{22}$	367·8	+3·3
Treasury Mountain to Tavaputs	1 415·0	2·2	$0=+3·0-x_{21}+x_{25}$	1 417·5	+2·5
Treasury Mountain to Mount Waas	340·3	1·4	$0=+3·7-x_{20}+x_{25}$	343·0	+2·7
Uncompahgre to Gunnison	2 012·5	8·0	$0=+0·5-x_{23}+x_{24}$	2 012·7	−0·2
Uncompahgre to Mesa	1 308·6	2·1	$0=+3·6+x_{22}-x_{23}$	1 307·3	+1·3
Uncompahgre to Mount Ellen	843·0	0·5	Rejected		
Uncompahgre to Mount Waas	599·5	2·2	$0=+1·5-x_{20}+x_{23}$	600·6	+1·1
Uncompahgre to Tavaputs	1 673·0	0·8	$0=+2·0-x_{21}+x_{23}$	1 675·1	+2·1
Uncompahgre to Treasury Mountain	257·1	5·6	$0=+0·1-x_{23}+x_{25}$	257·6	−0·5
Uncompahgre to Mount Ouray	102·3	6·3	$0=+1·3-x_{23}+x_{26}$	101·5	+0·8
Mount Elbert to Treasury Mountain	298·1	13·3	$0=+0·1+x_{25}-x_{27}$	297·7	+0·4
Mount Elbert to Uncompahgre	40·0	2·9	$0=+1·0-x_{23}+x_{27}$	40·1	+0·1
Mount Elbert to Mount Ouray	140·4	10·3	$0=+1·6-x_{26}+x_{27}$	141·6	+1·2
Mount Elbert to Pikes Peak	94·6	3·5	$0=+1·2+x_{27}$	95·2	+0·6
Mount Elbert to Bison	609·3	5·8	$0=+0·7+x_{27}-x_{28}$	607·8	−1·5
Mount Ouray to Treasury Mountain	154·8	8·9	$0=+1·2-x_{25}+x_{26}$	156·1	+1·3
Mount Ouray to Gunnison	1 911·3	17·5	$0=+0·3+x_{24}-x_{26}$	1 911·2	+0·1

Stations.	Δh.	p.	Observation equations.	Adjusted Δh.	Residuals.
	m.			*m.*	*m.*
Mount Ouray to Bison	469·0	4·1	$0=+1{\cdot}0-x_{26}+x_{28}$	466·2	+2·8
Mount Ouray to Plateau	2 608·9	3·1	$0=+1{\cdot}1+x_{26}$	2 609·8	+0·9
Bison to Divide	1 528·5	7·9	$0=+1{\cdot}7-x_{26}$	1 528·4	+0·1
Pikes Peak to Bison	511·5	16·7	$0=+2{\cdot}7-x_{28}$	512·6	+1·1
Pikes Peak to Mount Ouray	47·2	5·4	$0=+1{\cdot}0+x_{26}$	46·4	+0·8

No. 22.



The solution of the 28 normal equations gave the corrections to the assumed heights and the following values for the adjusted heights:

	Metres.	*Feet.*		*Metres.*	*Feet.*
Mount Como	2 748·2 =	9 016	Deseret	3 367·1 =	11 047
Pah-Rah	2 513·5	8 246	Scipio	2 967·0	9 734
Mount Grant	3 428·0	11 247	Wasatch	3 397·6	11 147
Carson Sink	2 680·8	8 795	Patmos Head	3 003·0	9 852
Toiyabe Dome	3 590·4	11 779	Mount Ellen	3 500·6	11 485
Lone Mountain	2 776·8	9 110	Mount Waas	3 754·7	12 319
Mount Callahan	3 111·3	10 208	Tavaputs	2 680·2	8 793
Diamond Peak	3 241·3	10 634	Mesa	3 047·9	10 000
White Pine	3 437·1	11 277	Uncompahgre	4 355·3	14 289
Wheeler Peak	3 980·2	13 058	Gunnison	2 342·6	7 686
Pioche	2 679·1	8 790	Treasury Mountain	4 097·7	13 444
Ibepah	3 688·5	12 101	Mount Ouray	4 253·8	13 956
Tushar	3 702·0	12 146	Mount Elbert	4 395·4	14 421
Mount Nebo	3 623·1	11 887	Bison	3 787·6	12 426

The resulting differences of height and the residuals from the observation equations are given in the last two columns of the preceding table of differences of height.

PROBABLE ERROR OF AN ADJUSTED HEIGHT.

The probable error of an observation of unit weight is found from the expression $\varepsilon_1 = 0.674\,5\sqrt{\frac{[pdd]}{n-c}}$, in which the d's are the residuals referred to above, n the number of observation equations, and c the number of normal equations. In this case $\varepsilon_1 = \pm 3.81$ metres.

To get the probable error of an adjusted height, we must divide this quantity by the square root of the weight coefficient derived from the normal equations. The computation was made for Deseret, being the station nearest the Salt Lake Base, with the result $p = 3.872$ and probable error of the height of Deseret $= \pm 1.94$ metres. This must be increased somewhat for the uncertainty of the starting heights at the two ends of the triangulation. For the probable error of the height of the Salt Lake Base ± 2.5 metres has been adopted.

For determining the elevation of the *Salt Lake Base* and *stations in the vicinity*, we have the heights of three stations fixed by the preceding adjustment, viz:

	Metres.
Ibepah	3 688·5
Deseret	3 367·1
Mount Nebo	3 623·1

From spirit leveling by the party of Assistant Eimbeck in 1888 and 1896 we have Salt Lake Northwest Base above Salt Lake Southeast Base 18·023 feet = 5·49 metres, and United States Engineers' Observatory (transit pier) above Salt Lake Northwest Base 141·824 feet = 43·23 metres. The approximate heights of the remaining stations are:

	Metres.
Pilot Peak	$3\,269+x_1$
Ogden Peak	$2\,925+x_2$
Antelope	$2\,017+x_3$
Promontory	$2\,016+x_4$
Waddoup	$1\,310+x_5$
City Creek	$1\,883+x_6$
Salt Lake Northwest Base ♦	$1\,296+x_7$
Salt Lake Southeast Base	$1\,296-5.5=1\,290.5+x_7$
United States Engineers' Observatory	$1\,296+43.2=1\,339.2+x_7$

The computed differences of heights with their weights and the corresponding observation equations are given in the following table. The long line from Ibepah to Ogden Peak is rejected:

4. TABLE OF DIFFERENCES OF HEIGHT.

Stations.	Δh.	p	Observation equations.	Adjusted Δh.	Residuals.
	m.			*m.*	*m.*
Ibepah to Pilot Peak	420·9	5·1	$0=+1·4+x_1$	421·1	−0·2
Ibepah to Ogden Peak	748·7	0·4	Reject		
Mount Nebo to Pilot Peak	349·7	0·7	$0=-4·4+x_1$	355·7	−6·0
Mount Nebo to Ogden Peak	695·3	2·7	$0=+2·8+x_2$	699·3	+4·0
Deseret to Pilot Peak	98·1	6·8	$0=\ 0·0+x_1$	99·7	−1·6
Deseret to Ogden Peak	443·4	8·8	$0=-1·3+x_2$	443·3	+0·1
Deseret to Antelope	1 352·4	20·6	$0=+2·3+x_3$	1 351·4	+1·0
Deseret to Waddoup	2 059·4	12·5	$0=+2·3+x_5$	2 059·3	−0·1
Deseret to Promontory	1 353·8	8·9	$0=+2·7-x_4$	1 353·2	−0·6
Pilot Peak to Ogden Peak	341·1	3·5	$0=+2·9+x_1-x_2$	343·6	+2·5
Pilot Peak to Promontory	1 252·1	3·4	$0=-0·9+x_1-x_4$	1 253·5	−1·4
Pilot Peak to Antelope	1 250·8	2·2	$0=+1·2+x_1-x_3$	1 251·7	+0·9
Ogden Peak to Antelope	908·0	74·0	$0=\ 0·0+x_2-x_3$	908·1	+0·1
Ogden Peak to United States Engineers' Observatory	1 585·9	472·0	$0=+0·1-x_2-x_7$	1 585·7	+0·2
Ogden Peak to Waddoup	1 615·4	57·8	$0=+0·4-x_2+x_5$	1 616·0	−0·6
Ogden Peak to Promontory	909·3	18·6	$0=+0·3-x_2+x_4$	909·9	−0·6
Ogden Peak to Southeast Base	1 634·2	75·5	$0=+0·3+x_2-x_7$	1 634·4	+0·2
Ogden Peak to Northwest Base	1 628·7	79·4	$0=+0·3+x_2-x_7$	1 628·9	−0·2
Antelope to Promontory	1·5	66·1	$0=+0·5-x_3+x_4$	1·8	−0·3
Antelope to Waddoup	708·1	149·0	$0=+1·1-x_3+x_5$	707·9	+0·2
Antelope to Southeast Base	726·2	113·2	$0=+0·3+x_3-x_7$	726·3	+0·1
Antelope to Northwest Base	720·9	121·6	$0=+0·1+x_3-x_7$	720·8	−0·1
Waddoup to Southeast Base	17·8	62·7	$0=+1·7+x_5-x_7$	18·4	+0·6
Promontory to Northwest Base	719·2	29·3	$0=-0·8+x_4-x_7$	719·0	−0·2
Promontory to Waddoup	704·8	30·1	$0=+1·2+x_4-x_5$	706·1	+1·3
Northwest Base to Southeast Base	4·8	232·8	By spirit levels=	(5·49)	
Antelope to City Creek	133·5	26·7	$0=+0·5+x_3-x_6$	133·9	+0·4
Ogden Peak to City Creek	1 042·5	19·7	$0=+0·5-x_2+x_6$	1 042·0	+0·5

The solution of the resulting normal equations gave the corrections to the approximate heights and the following values of the adjusted heights:

	Metres.		*Feet.*
Pilot Peak	3 267·4	=	10 720
Ogden Peak	2 923·8		9 592
Antelope	2 015·7		6 613
Promontory	2 013·9		6 607
Waddoup	1 307·8		4 291
City Creek	1 881·8		6 174
Salt Lake Northwest Base	1 294·9		4 248
Salt Lake Southeast Base	1 289·4		4 230
United States Engineers' Observatory transit pier	1 338·1	=	4 390

The height of this pier as given by Lieut. G. M. Wheeler in his report on Surveys West of the One Hundredth Meridian is 4 374 feet, based on railroad levels at Ogden.

For determining the elevation of the bench mark at Grand Junction Standpipe there are the following differences of height:

Stations.	Δh.	p.	Adjusted Δh.	Residuals.
	m.			*m.*
Tavaputs to Chiquita	73·3	2·8	74·5	1·2
Mesa to Chiquita	442·3	17·8	442·2	0·1
Mesa to Standpipe	1 643·2	20·1	1 642·6	0·6
Tavaputs to Standpipe	1 273·6	9·6	1 274·9	1·3
Chiquita to Standpipe	1 200·4	110·4	1 200·4	0·0
Resulting heights—Chiquita		2 605·5 metres = 8 549 feet.		
Grand Junction Standpipe		1 405·3 metres = 4 611 feet.		

A line of levels was run by the party of Assistant W. Eimbeck in 1895 between the Standpipe bench mark and the ground in the center of the track in front of the Denver and Rio Grande Railroad station at Grand Junction, which showed the latter point to be 27·27 feet lower than the bench mark to which the vertical measures refer. Hence the elevation of roadbed at Grand Junction station is 4 584 feet. In Bulletin No. 76 of the United States Geological Survey this height is given as 4 579 feet, as derived from the railroad levels.

The height of the track at the summit of Marshall Pass, as determined from zenith distances, measured at Mount Ouray is 3 302·3 metres, or 10 834 feet. The height of the same point derived from railroad levels is 10 841 feet.

For the height of Mount Conness, in California, we have from reciprocal zenith distances Mount Conness 408·7 metres higher than Mount Grant, or 3 836·7 metres high, and from zenith distances at Round Top and an assumed coefficient of refraction Mount Conness higher than Round Top 669 metres, or 3 834·6 metres high. The weights of the two determinations are 6·4 and 5·3, respectively; hence the weighted mean result is 3 835·8 metres, or 12 585 feet. Notwithstanding this seeming accord we place little reliance upon this result on account of the weakness of connecting* observations with the main series of heights. The result may be taken rather as an upper limit. A communication from the Director of the United States Geological Survey, dated November 15, 1898, gives the approximate height of Mount Conness 12 556 feet, as determined from a combination of two lines of spirit levels and measures of vertical angles, the former operation starting from San Francisco Bay at Oakland. The United States Engineers gave the height 12 552 feet (determined in 1878–79). The difference between these results is $\frac{37}{12584}$, or $\frac{1}{340}$ part of the height.

We conclude this paper by giving a few comparisons with heights roughly determined, all except two being *barometric*. Some are by the United States Engineers in connection with their early explorations of the Rocky Mountain region in part traversed by our triangulation, and are published in United States Geographical Surveys West of the One Hundredth Meridian, etc., Captain G. M. Wheeler, United States Army, 1883, Washington, D. C., 1885, and some by Dr. Hayden and Major Powell in connection with their early geological surveys.

* The station Mount Conness was introduced into the triangulation eleven years after the work in this region had been done, and when it was then too expensive to secure full connection with other stations.

Elevation in feet from—	Old determinations.	Coast and Geodetic Survey.
Pikes Peak (U.S.Sig.O.) from levels	14 134	14 108
Bison (Hayden)	12 237	12 426
Mount Ouray (Hayden)	14 043	13 956
Mount Elbert (Hayden)	14 351	14 421
Mount Elbert (U.S.E.)	14 101	
Treasury Mountain (Hayden)	13 200	13 444
Uncompahgre (Hayden)	14 235	14 289
Uncompahgre (U.S.E.)	14 408	
Mount Waas (Hayden)	12 561	12 319
Mount Ellen (Powell)	11 410	11 485
Patmos Head (Powell)	9 830	9 852
Beaver or Baldy (U.S.E.)	11 730	12 085
Tushar or Mount Belknap (Powell)	12 200	12 146
Tushar or Mount Belknap (U.S.E.)	11 894	
Ogden Peak or Observatory Peak (U.S.E.)	9 589	9 592
Antelope (U.S.E.)	6 660	6 613
Ogden Observatory (U.S.E.) from levels	4 374	4 390
Pilot Peak or Pilot Knob (U.S.E.)	10 758	10 720
Wheeler Peak or Union Peak (U.S.E.)	13 063	13 058
Toiyabe Dome or Poston (U.S.E.)	11 978	11 779
Mount Grant or Cory (U.S.E.)	11 326	11 247
Mount Como (U.S.E.)	9 017	9 016

Considering the means available at the time of the early determinations, the differences above indicated are not excessive.

ROUND TOP, CALIFORNIA, LOOKING EAST.

PART III.

THE MAIN TRIANGULATION AND ITS CONNECTION WITH THE BASE NETS.

CONTENTS OF PART III.

III. THE MAIN TRIANGULATION BETWEEN CAPE MAY, N. J., AND POINT ARENA, CAL., AND ITS CONNECTION WITH THE BASE NETS.

A. INTRODUCTION.

In this part of the account of the arc devoted to the triangulation proper, there is given for each series a sketch with general description of the region traversed. Reference is made to facilities found or obstructions encountered.

There are also introduced a few photographic illustrations relating to instruments, topography, or field work of the party that may possess special interest.

It was thought unnecessary to burden this part with a description of the stations, as had been done for the base nets, since such detailed descriptions are on file in the Archives of the Survey and copies can be furnished on application by anyone who may require them. An exception was made with the high mountain stations in the western part of the arc, for which abbreviated descriptions were introduced, omitting topographic sketches.

This triangulation extends over a distance of about 4 425 kilometres, or 2 750 statute miles, measured along its middle course or axis, and is most conveniently described and treated by considering it in parts or subdivisions made by the interspersed base nets.

These divisions of the triangulation will be treated and referred to under the following designations:

SUBDIVISION.	NAME OF CHAIN OF TRIANGULATION.
1 Atlantic coast to Kent Island Base	The Eastern Shore series
2 Kent Island Base to St. Albans Base	The Allegheny series
3 St. Albans Base to Holton Base	The Ohio series
4 Holton Base to Olney Base	The Indiana series
5 Olney Base to American Bottom Base	The Illinois series
6 American Bottom Base to Versailles Base	The Missouri series
7 Versailles Base to Salina Base	The Missouri-Kansas series
8 Salina Base to El Paso Base	The Kansas-Colorado series
9 El Paso Base to Salt Lake Base	The Rocky Mountain series
10 Salt Lake Base to Yolo Base	The Nevada series
11 Yolo Base to Pacific coast	The Western or Coast Range series

B. THE DISTRIBUTION OF THE BASE LINES ALONG THE ARC.

The distribution of the base lines as parts of the connected chain of triangles stretching from ocean to ocean, is shown by the table below, which gives the distance of each base (middle point) from its next neighbor to the westward, as measured along the middle of the intervening triangulation.

ADJACENT BASE LINES.	APPROXIMATE DISTANCES.	
	Kilometres.	*Statute miles.*
Kent Island to St. Albans	545	339
St. Albans to Holton	330	205
Holton to Olney	238	148
Olney to American Bottom	174	108
American Bottom to Versailles	241	150
Versailles to Salina	419	260
Salina to El Paso	605	376
El Paso to Salt Lake*	653+217	406+135
Salt Lake* to Yolo	854+217	531+135

The distance from Kent Island to the capes of the Delaware Bay is 180 kilometres, or 112 statute miles, nearly, and the distance from the Yolo Base to Point Arena on the Pacific 186 kilometres, or 115 statute miles. Total development across the continent 4 425 kilometres, or 2 750 statute miles, nearly.

C. GENERAL METHOD OF TREATMENT OF THE TRIANGULATION.

Each link of triangulation connecting two adjacent base nets is adjusted by itself in order that its geometrical conditions be satisfied, and in addition thereto that the lengths of two base lines be in accord. The linear dimensions of the base nets, as given in Part I, are taken as fixed, and the dispersion of any discrepancy between them as indicated by the intervening triangulation is thrown upon the latter.

As in the case of the treatment of the base nets, a sketch and an abstract of the results of the local or *station* adjustment † of the horizontal direction measures is given for

*The middle of Salt Lake Base is in longitude 112° 04′ and lies about 217 kilometres (135 statute miles) to the north of the middle line of the triangulation between the El Paso and Yolo bases; the direct distance between these base lines is 1 507 kilometres or 937 statute miles, nearly.

†The *station* adjustment of observed directions is carried out as usual by Bessel's method; the observations are taken as of equal weight and the resulting directions (or angles) are directly introduced into the triangulation, where they are made subject to a further adjustment—namely, that known as the *figure* adjustment. The full application of Bessel's method (Gradmessung in Ostpreussen, etc., by F. W. Bessel, Berlin, 1838; § 15 and § 34; also Clarke's Geodesy, Oxford, 1880, pp. 233–237; and Wright's Adjustment of Observations, New York, 1884, p. 315 and fol.) demands the carrying over of the local weight conditions into the general conditions of the triangulation, a process which is not followed on the Survey where the two dissimilar operations are kept distinct, for the following satisfactory reasons: In the first place, in any extended or complicated triangulation the establishment and simultaneous solution of a large number of equations, as demanded by theoretical rigor, becomes unwieldly and may become impracticable, and the labor should be lessened by any concession to the demands of expediency that can be justified. Secondly, the consideration of different weights to the results from the local adjustment of measures of directions favors separate treatment of local and figure adjustments, since the errors met with and inherent to the second operation are of an entirely *distinct* character from those developed in the local adjustment; thus, for instance, effects of imperfect centering of instrument, defective position of heliotrope sighted, persistent local deflection of line of sight, and particularly effect of local deflection of the vertical at a station, are all sources of error which form no part of the discrepancies met with in the local measures, whereas they appear fully in the discords found in the sums of angles of the triangles or in the ratios of their sides. The discrepancies in the local measures are for the greater part due to defective graduation or want of adjustment of instrument, to irregular lateral refraction, defective illumination of object sighted, and to other causes.

each station; this is followed by the presentation of the conditional, the correlate, and the normal equations of the general or *figure* adjustment, together with the resulting corrections and the finally adjusted triangle sides and angles.

There is appended to each abstract of directions at a station the probable error of a single measure, i. e., of a pointing and readings with telescope direct, motion forward in series, and a pointing with readings with telescope reversed, motion backward in series. Its value is $e_1 = \sqrt{\frac{0.455 \, \Sigma\triangle^2}{n - s - d + 1}}$ where n = number of observations, s = number of series, and d = number of directions, and $\Sigma\triangle^2$ the sum of squares of differences from the true values. In a few exceptional cases where repeating theodolites were used, six repetitions direct and six repetitions reversed, combined to a mean, may be taken as a unit of measure and is so indicated. A rough approximation for the probable error of a resulting direction, as given for instance in the case of the Yolo Base Net, may be had by $e_1 = \sqrt{\frac{0.455 \, \Sigma\triangle^2}{(s-1)\,(\text{diag. coeff.})}}$; here s = number of series for the particular direction. These probable errors are introduced for the purpose of giving in a general way information respecting the performance of the instrument.

D. THE PRECISION OF THE ADJUSTED TRIANGULATION.

For the purpose of obtaining an approximate measure of the precision reached for the various parts of the triangulation, the following formulæ and method were made use of. The mean error of any angle of an adjusted series of triangles is given by the formula $m = \sqrt{\frac{2\,[pvv]}{c}}$ where m = mean error of an angle.

$v_1 \, v_2 \, . \; . \; . \; v_n$ = corrections to the *directions* due to the adjustment of the triangulation.

c = number of conditions involved.

Supposing all angles of unit weight, we have for the reciprocal of the weight of a side the expression *—

$$u_{a_n} = \tfrac{2}{3}\,(\delta a_n)^{-2}\, \Sigma_{a_1}^{a_n} \left[\delta^n{}_A + \delta_A \delta_B + \delta^2{}_B\right]$$

hence for the *mean* error of the side a_n the relation $m_{a_n} = m\sqrt{u_{a_n}}$

here A = angle adjacent to a base and opposite to the next or continuation base side of a string of triangles between the sides a_1 and a_n.

B = angle opposite a preceding base side.

δ_a = tabular logarithmic difference of a unit of length of the side a_n.

* In the Ordnance Survey of Great Britain and Ireland, London, 1858, p. 421, the expression—

$$\pm \frac{\epsilon}{3} A_2 \sqrt{\Sigma(\cot^2 \alpha_n + \cot \alpha_n \cot \beta_n + \cot^2 \beta_n)}$$

for the probable error of the side A_2 is quoted from Laplace's Théorie analytique des probabilités. When put in convenient shape for logarithmic computation, we have the form as given in the text. Cf. T. W. Wright's "Treatise on the adjustment of observations," New York, 1884, pp. 224, 234; also W. Jordan's "Vermessungskunde," Vol. III (1896) p 110, and A. R. Clarke's "Geodesy," Oxford, 1880, pp. 64, 226.

δ_A and δ_B = tabular logarithmic differences corresponding to a change of 1″ in the angles A and B in a table of logarithms of sines.

u_{a_n} and m_{a_n} = the reciprocal of the weight of side a_n and its mean error respectively.

In applying the above formulæ to an extended triangulation, such, for instance, as joins two adjacent base nets, or, as in another case, reaches from a base net to the coast line, we can suppose the same to be made up of a string of single triangles between the initial and final sides. This selected chain of triangles should be composed of the best shaped and best measured triangles, and their number should be as small as may be.

The probable error of any side of a series of triangles due to the angular measures can thus be computed, and when combined with that arising from the measure of the base and the angles of the base net, the probable error of any side will become known, and when expressed in terms of its length the relative precision of the triangulation can be deduced.

For any line between two base nets let p_1 and p_2 be its weights deduced when passing to it from either base net; then $P = p_1 + p_2$ and the probable error of the line $= 1/\sqrt{P}$. In passing through the triangulation in opposite directions the A's and B's remain the same, but there is an interchange of the letters. To find the uncertainty in the developed length of a triangulation, it was divided into suitable sections and the probable error of each junction line was computed as above. Then the proportional error for each section is taken as the mean beween the corresponding probable errors of the terminal lines. This proportional probable error multiplied by the length of the section gives the probable error of the length, and the sum of these quantities for the several sections gives the probable error of the developed length of the triangulation.

E. LENGTH OF SIDES OF BASE NETS.

The following table contains the logarithms of the length of sides required for establishing the equations, which bring the adjacent base nets into accord. Later these same logarithms serve for the triangle side computations:

Recapitulation of resulting lengths of sides of base nets which form the connection of adjacent bases by means of the intervening triangulations.

Base net.	Connecting side.	Logarithm of length.	Probable error of length: In units of seventh place of log.	Probable error of length: In metres.	Probable error of length: In parts of length.
Kent Island Base, Maryland	Finlay to Pooles Island	4·419 418 8	....	....	....
	Finlay to Linstid	4·550 316 3	±40	±0·33	$\frac{1}{107\,000}$
	Pooles Island to Linstid	4·462 716 4	....	....	....
	Webb to Marriott	4·392 324 7	39	0·22	$\frac{1}{112\,000}$
St. Albans Base, West Virginia	Summersville to Ivy	4·888 948 7	27	0·48	$\frac{1}{161\,000}$
	Piney to Pigeon	4·378 842 6	22	0·12	$\frac{1}{199\,000}$
Holton Base, Indiana	Reizin to Culbertson	4·387 791 5	15	0·08	$\frac{1}{297\,000}$
	Green to Stout	4·453 827 3	14	0·09	$\frac{1}{316\,000}$

Recapitulation of resulting lengths of sides of base nets which form the connection of adjacent bases by means of the intervening triangulations—Continued.

Base net.	Connecting side.	Logarithm of length.	Probable error of length: In units of seventh place of log.	In metres.	In parts of length.
Olney Base, Illinois	Hunt City to Oblong	4·156 114 3	15	0·05	$\frac{1}{288\,000}$
	Hunt City to Newton	4·307 622 1	15	0·07	$\frac{1}{290\,000}$
	Hunt City to Claremont	4·535 016 4	15	0·12	$\frac{1}{286\,000}$
American Bottom Base, Illinois	Sugarloaf to Clarks Mound	4·164 534 3	57	0·19	$\frac{1}{77\,000}$
	Clarks Mound to Dreyer	4·149 726 7	52	0·17	$\frac{1}{83\,000}$
	Minoma to Insane Asylum	4·025 166 1	53	0·13	$\frac{1}{81\,000}$
	Insane Asylum to Kleinschmidt	4·065 715 2	58	0·15	$\frac{1}{78\,000}$
Versailles Base, Missouri	Christian to Belshe	4·486 091 7	17	0·12	$\frac{1}{255\,000}$
	Hubbard to Hughes	4·439 731 1	13	0·08	$\frac{1}{334\,000}$
	Christian to High Point	4·187 515 2	17	0·06	$\frac{1}{257\,000}$
	High Point to Belshe	4·305 854 3	17	0·08	$\frac{1}{257\,000}$
Salina Base, Kansas	Vine Creek to Iron Mound	4·534 704 9	16	0·13	$\frac{1}{284\,000}$
	Thompson to Heath	4·499 188 0	22	0·16	$\frac{1}{197\,000}$
El Paso Base, Colorado	Divide to Big Springs	4·623 059 03	12	0·12	$\frac{1}{350\,000}$
	Big Springs to Holcolm Hills	4·452 618 46	12	0·08	$\frac{1}{350\,000}$
Salt Lake Base, Utah	Ibepah to Mount Nebo	5·265 702 68	16	0·67	$\frac{1}{275\,000}$
	Pilot Peak to Ibepah	5·124 323 42	....	....	....
Yolo Base, California	Mount Helena to Mount Diablo	5·032 332 46	11·9	0·295	$\frac{1}{365\,000}$
	Mount Tamalpais to Mount Diablo	4·779 637 67	13·0	0·18	$\frac{1}{335\,000}$

F. THE TRIANGULATION.

I. THE EASTERN SHORE SERIES OF TRIANGLES, 1844–45 AND 1896–97.

(*a*) *Introduction.*

Before it was contemplated to measure an arc of parallel in latitude 39°, there had already been made a geodetic connection between the Kent Island Base and the Capes of the Delaware Bay; this old triangulation extended up the Chesapeake Bay to its head and crossed over to the Delaware Bay and down that bay to its Capes.

On examination it was found to possess insufficient strength and undesirable linear extension for incorporation into the transcontinental triangulation, and in consequence a new and more direct connection was made in 1896–97.

This field work proved one of great difficulty, although the direct distance is not much over 135 kilometres or 84 statute miles. The length of the triangulation measured from the middle of the lines Finlay to Linstid and Cape May Light to Cape Henlopen Light, and along the middle of the series, is about 140 kilometres or 87 statute miles.

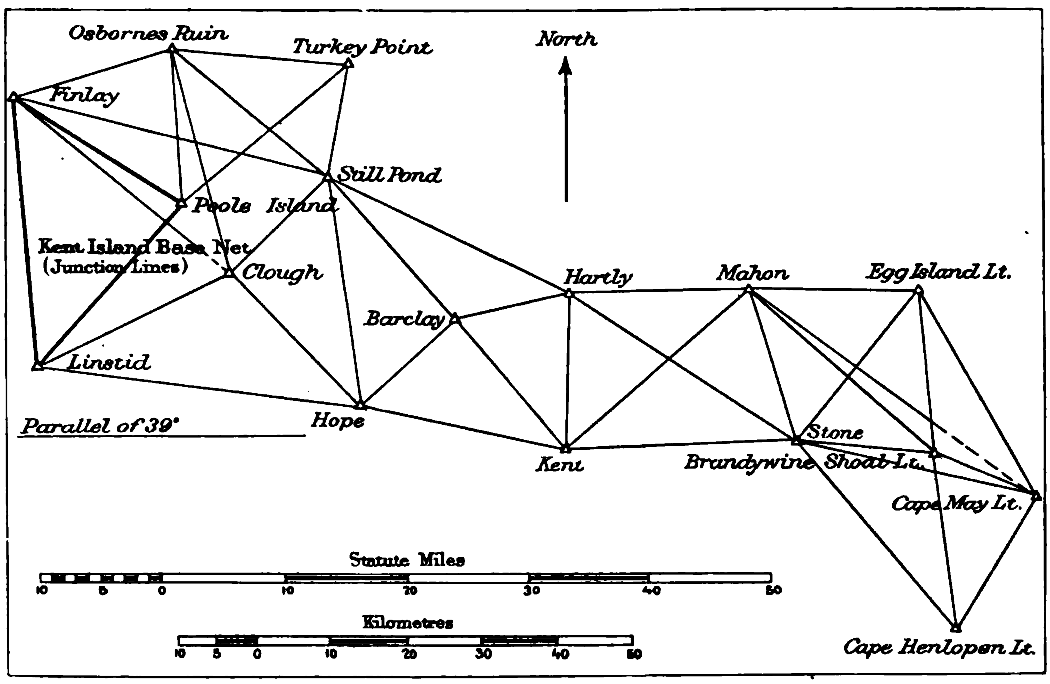
The new triangulation was in charge of F. W. Perkins, Assistant Coast and Geodetic Survey, by whom the following description of the region covered and the means employed by him was furnished:

The Eastern Shore section crosses the Delaware Bay, the State of Delaware, the Eastern Shore of Maryland, the Chesapeake Bay, and terminates on the high land north and south of Baltimore; one-

third being over water and two-thirds over land. The land rises gradually from the marshy shores on the western side of Delaware Bay to an elevation of 70 feet near the center of the peninsula, and again falls away to the Chesapeake, the surface inequalities being nowhere considerable. It rises again from the deeply indented shore line on the western side of the Chesapeake to 80 feet at Linstid south of Baltimore, and to 480 feet at Finlay to the north, with well-marked irregularities of surface. The land is generally under a high state of cultivation with extensive areas of orchards, but with only occasional clumps of forest growth, excepting on the flanks of the peninsular crest.

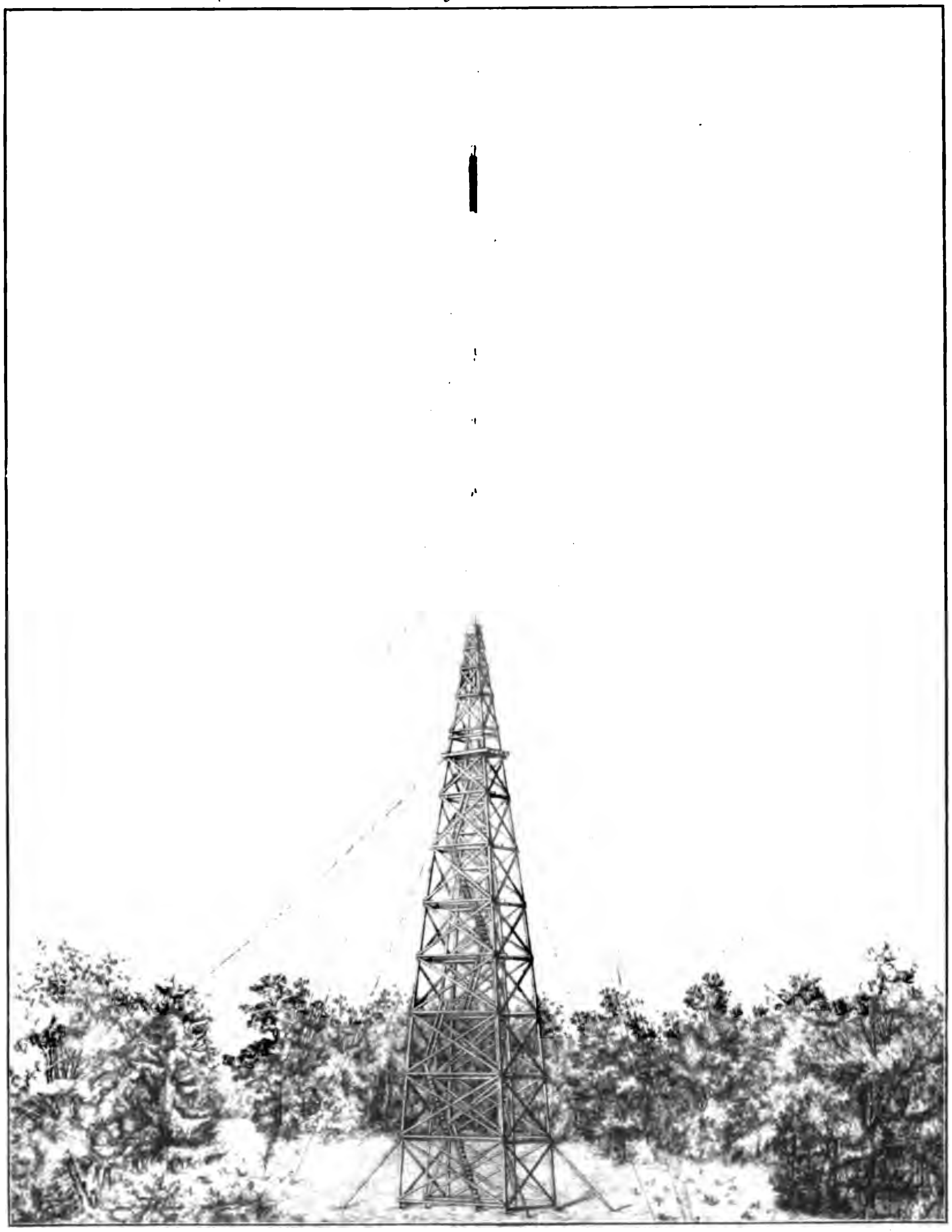
To overcome the natural and artificial obstructions, high signals were found necessary; at six o those on the peninsula the instrument was mounted 120 feet (36·6 metres) above the ground, and the targets observed on were in some instances as much as 260 feet (79·2 metres) above the ground. The latter were so carefully secured by opposing wire-guys that no movement observable in the transi. telescopes, mounted for the purpose, was produced by two or three men swaying upon the guys.

No. 24.



Respecting the number of positions or the number of repetitions taken by the several observers with their several instruments, no definite statement can be made except that a sufficient number of series of six repetitions of the angles were secured, and that in case of observations of directions by Assistant Perkins's party the circle was used in twelve positions with at least two complete series in each.

With a view of reducing the labor of adjustment as much as possible without perceptible sacrifice of accuracy, the triangulation has been adjusted in two sections with the single line Hartly to Kent in common. In the first part 18 conditions and in the second part 15 conditions had to be satisfied.



OBSERVING STATION, STILLPOND, MD.

Elevation of instrument above ground, 36½ meters or 120 feet Elevation of target, 84 meters or 275 feet.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment.*

[Abstract of directions at stations of part (1).]

Linstid, Anne Arundel County, Maryland. May 24 to June 26, 1848. 60-centimetre theodolite, No. 2. A. D. Bache, observer. January 8 to January 31, 1897. 30-centimetre theodolite, No. 16. F. W. Perkins and W. B. Fairfield, observers. Telescope above ground 27·89 metres in 1897.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
	Finlay	0	00	00·00	+0·70		00·70
	Pooles Island	46	42	57·73	−0·18		57·55
4	Clough	69	13	07·73		+0·72	08·45
	Swan Point	77	13	16·97	−0·52		16·45
5	Hope	102	07	23·10		+0·95	24·05
	Kent Island North Base	140	56	37·60	−0·26		37·34
	Taylor	175	43	02·43	+0·75		03·18
	Marriott	209	40	11·23	−0·50		10·78
	Webb	275	58	53·59	+0·02		53·61
				Mean	0·00		

Probable error of a single observation of a direction— (*D.* and *R.*) $= \pm 1''\cdot12$ in 1848.
(6 *D.* and 6 *R.*) $= \pm 0''\cdot73$ in 1897.

Finlay, Baltimore County, Maryland. August 29 to September 11, 1844. 60-centimetre theodolite, No. 2. J. Ferguson, observer. October 15 to December 27, 1896. 30-centimetre theodolite, No. 16. G. A. Fairfield, observer. Telescope above ground 1·5 metres in 1896.

No. of direction.	Objects observed.	°	′	″	″	″	″
1	Osbornes Ruin	0	00	00·00		+0·17	00·17
2	Still Pond	30	48	41·95		−0·88	41·07
	Pooles Island	48	03	34·15	+0·48		34·63
3	Clough	55	23	20·93		−0·79	20·14
	Linstid	101	36	01·26	−0·72		00·54
	Webb	127	19	37·46	+0·25		37·71
	Rosanne	159	25	03·26			
				Mean	0·00		

Probable error of a single observation of a direction— (*D.* and *R.*) $= \pm 1''\cdot52$ in 1844.
(6 *D.* and 6 *R.*) $= \pm 0''\cdot65$ in 1896.

Pooles Island, Harford County, Maryland. May 17 to May 27, 1848. 30-centimetre theodolite, No. 11. E. Blunt, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
	Swan Point	0	00	00·00	+0·30		00·30
	Linstid	36	22	15·13	+0·17		15·30
	Finlay	116	06	54·92	−0·47		54·45
6	Osbornes Ruin	170	34	06·56		−1·20	05·36
7	Turkey Point	225	05	01·56		−0·01	01·55
				Mean	0·00		

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) $= \pm 0''\cdot69$.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Hope, Queen Anne County, Maryland. November 9 to December 29, 1896. 30-centimetre theodolite, No. 37. F. W. Perkins, observer. Telescope above ground 37·03 metres.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″
28	Linstid	0	00	00·00	−0·57	59·43
29	Clough	38	17	06·79	−0·85	05·94
30	Still Pond	73	55	56·23	+0·41	56·64
31	Barclay	129	50	35·05	+0·94	35·99
32	Kent	184	18	04·64	+0·06	04·70

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ±0″·57.

Barclay, Queen Anne County, Maryland. January 3 to February 17, 1897. 30-centimetre theodolites, Nos. 16 and 37. G. A. Fairfield and W. B. Fairfield, observers. Telescope above ground 27·89 metres.

		°	′	″	″	″
35	Still Pond	0	00	00·00	+0·30	00·30
36	Hartly	115	57	00·02	+0·33	00·35
33	Kent	178	56	52·85	+0·30	53·15
34	Hope	267	59	30·19	−0·94	29·25

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ±0″·71.

Osbornes Ruin, Harford County, Maryland. September 23 to October 2, 1844. 60-centimetre theodolite, No. 2. J. Ferguson, observer. August 17 to September 20, 1896. 30-centimetre theodolite, No. 16. G. A. Fairfield, observer. Telescope above ground 14·17 metres in 1896.

		°	′	″	″	″
8	Turkey Point	0	00	00·00	+0·11	00·11
9	Still Pond	34	55	30·47	+0·13	30·60
10	Clough	70	51	37·77	−0·09	37·68
11	Pooles Island	81	27	17·53	−0·06	17·47
12	Finlay	158	56	33·29	−0·09	33·20
	Principio	324	49	48·33		

Probable error of a single observation of a direction— (*D.* and *R.*) = ±1″·33 in 1844.
(6 *D.* and 6 *R.*) = ±0″·35 in 1896.

Turkey Point, Cecil County, Maryland. May 31 to June 17, 1845. 60-centimetre theodolite, No. 2. J. Ferguson, observer. September 30 to October 19, 1896. 35-centimetre theodolite, No. 10. J. Nelson, observer. Telescope above ground 2·08 metres in 1896.

		°	′	″	″	″
26	Pooles Island	0	00	00·00	+0·65	00·65
27	Osbornes Ruin	44	01	48·72	−0·44	48·28
	Principio	131	14	41·24		
	Buck 2	196	36	01·81		
25	Still Pond	320	56	58·83	−0·20	58·63

Probable error of a single observation of a direction— (*D.* and *R.*) = ±1″·49 in 1845.
(*D.* and *R.*) = ±0″·62 in 1896.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Clough, Kent County, Maryland. August 17 to October 19, 1896. 30-centimetre theodolite, No. 135. Telescope above ground 23·32 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
16	Still Pond	0 00 00·00	−0·24	59·76
17	Hope	90 03 44·90	+0·49	45·39
13	Linstid	198 52 25·31	−0·31	25·00
14	Finlay	263 26 41·03	−1·80	39·23
15	Osbornes Ruin	299 58 23·58	+1·85	25·43

Probable error of a single observation of a direction (*D.* and R.) = ± 0″·88.

Still Pond, Kent County, Maryland August 19 to October 31, 1896. 30-centimetre theodolite, No. 37. Telescope above ground 37·03 metres. F. W. Perkins, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
21	Clough	0 00 00·00	−0·18	59·82
22	Finlay	58 52 00·65	+1·22	01·87
23	Osbornes Ruin	84 02 19·46	+0·13	19·59
24	Turkey Point	146 02 00·39	−0·04	00·35
18	Hartly	249 38 35·97	−0·71	35·26
19	Barclay	273 37 44·66	−0·29	44·37
20	Hope	305 42 35·16	−0·14	35·02

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ± 0″·59.

Hartly, Kent County, Delaware. September 5 to September 14, 1896. 30-centimetre theodolite, No, 145. Telescope above ground 37·03 metres. J. Nelson, observer. October 31, 1896 to January 4. 1897. 35-centimetre theodolite, No. 10. Telescope above ground 31·34 metres. J. Nelson and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
37	Kent	0 00 00·00	−0·37	59·63
38	Barclay	73 23 04·60	−0·32	04·28
39	Still Pond	113 26 55·36	+0·69	56·05
	Mahon	268 21 29·49	−0·10	29·39
	Stone	302 01 54·00	+1·34	55·34

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·85

Kent, Kent County, Delaware. October 28 to December 10, 1896. 30-centimetre theodolite, No. 135. Telescope above ground 38·56 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
42	Hartly	0 00 00·00	+0·36	00·36
	Mahon	47 34 08·56	−0·74	07·82
	Stone	86 42 27·68	−0·38	27·30
40	Hope	279 53 00·96	−0·07	00·89
41	Barclay	316 22 57·30	−0·29	57·01

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·75.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

[Abstract of directions at stations of part (2).]

Hartly, Kent County, Delaware. September 5 to September 14, 1896. 30-centimetre theodolite, No. 145. Telescope above ground 37·03 metres. J. Nelson, observer. October 31, 1896, to January 4, 1897. 35-centimetre theodolite, No. 10. Telescope above ground 31·34 metres. J. Nelson, and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net and figure adjustment.	Corrections from second figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
	Kent	0	00	00·00	−0·37		59·63
	Barclay	73	23	04·60	−0·32		04·28
	Still Pond	113	26	55·36	+0·69		56·05
1	Mahon	268	21	29·49		−0·10	29·39
2	Stone	302	01	54·00		+1·34	55·34
				Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·85.

Kent, Kent County, Delaware. October 28 to December 10, 1896. 30-centimetre theodolite, No. 135. Telescope above ground 38·56 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
	Hartly	0	00	00·00	+0·36		00·36
3	Mahon	47	34	08·56		−0·74	07·82
4	Stone	86	42	27·68		−0·38	27·30
	Hope	279	53	00·96	−0·07		00·89
	Barclay	316	22	57·30	−0·29		57·01
				Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·75.

Cape Henlopen Light-house, Sussex County, Delaware. May 24 to June 21, 1896. 30-centimetre theodolite, No. 16. Telescope above mean sea level 36·68 metres. G. A. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″
31	Stone	0	00	00·00	0·03	59·97
32	Brandywine Shoal Light-house	34	13	26·27	−0·27	26·00
33	Cape May Light-house	72	22	43·32	+0·29	43·61

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ±0″·46.

Brandywine Shoal Light-house, Kent County, Delaware. June 4 to June 12, 1896. 30-centimetre theodolite, No. 37. W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″
25	Cape May Light-house	0	00	00·00	+0·87	00·87
26	Cape Henlopen Light-house	59	46	25·73	−0·45	25·28
22	Stone	161	12	27·41	−0·03	27·38
23	Mahon	196	59	28·62	−0·39	28·23
24	Egg Island Light-house	240	34	06·20	+0·01	06·21

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ±0″·53.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Mahon, Kent County, Delaware. July 28 to August 30, 1896. 30-centimetre theodolite, No. 145. Telescope above ground 37·03 metres. J. Nelson, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″
8	Stone	0	00	00·00	+1·39	01·39
9	Kent	66	59	43·34	+1·01	44·35
10	Hartly	107	47	07·96	−0·08	07·88
5	Egg Island Light-house	287	48	50·22	−0·40	49·82
6	Cape May Light-house	323	12	11·35	−0·16	11·19
7	Brandywine Shoal Light-house	328	22	35·48	−1·75	33·73

Probable error of a single observation of a direction ($D.$ and $R.$) $= \pm 0''\!\cdot 65$.

Stone, Kent County, Delaware. June 18 to July 21, 1896. 30-centimetre theodolite, No. 145. Telescope above ground 37·03 metres. J. Nelson, observer.

No. of direction.	Objects observed.	°	′	″	″	″
15	Brandywine Shoal Light-house	0	00	00·00	−0·05	59·95
16	Cape May Light-house	8	11	43·72	+0·29	44·01
17	Cape Henlopen Light-house	44	20	32·22	+0·68	32·90
11	Kent	173	32	28·26	+0·19	28·45
12	Hartly	208	51	59·81	−1·00	58·81
13	Mahon	247	24	28·10	−0·54	27·56
14	Egg Island Light-house	304	50	36·21	+0·42	36·63

Probable error of a single observation of a direction ($D.$ and $R.$) $= \pm 1''\!\cdot 20$.

Egg Island Light-house, Cumberland County, New Jersey. July 4 to July 25, 1896. 30-centimetre theodolite, No. 37. W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″
18	Cape May Light-house	0	00	00·00	+0·18	00·18
19	Brandywine Shoal Light-house	23	46	60·03	−0·24	59·79
20	Stone	69	15	59·85	−1·21	58·64
21	Mahon	119	38	37·87	+1·27	39·14

Probable error of a single observation of a direction (6 $D.$ and 6 $R.$) $= \pm 0''\!\cdot 75$.

Cape May Light-house, Cape May County, New Jersey. June 30 to July 19, 1896. 30-centimetre theodolite, No. 16. Telescope above mean sea level 48·18 metres. G. A. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″
27	Cape Henlopen Light-house	0	00	00·00	+0·08	00·08
28	Stone	71	28	28·59	+0·55	29·14
29	Brandywine Shoal Light-house	82	04	20·49	−1·68	18·81
	Mahon	93	53			23·97*
30	Egg Island Light-house	118	51	24·17	+1·05	25·22

Probable error of a single observation of a direction (6 $D.$ and 6 $R.$) $= \pm 0''\!\cdot 48$.

*Computed value.

(*c*) *Figure adjustment.*

Observation equations of section (1).

No.	
1	$0 = +1{\cdot}41 - (1) + (6) - (11) + (12)$
2	$0 = -0{\cdot}03 - (3) + (4) - (13) + (14)$
3	$0 = -2{\cdot}68 - (1) + (3) - (10) + (12) - (14) + (15)$
4	$0 = -3{\cdot}06 - (2) + (3) - (14) + (16) - (21) + (22)$
5	$0 = +2{\cdot}37 - (1) + (2) - (9) + (12) - (22) + (23)$
6	$0 = +0{\cdot}39 - (8) + (9) - (23) + (24) - (25) + (27)$
7	$0 = +0{\cdot}07 - (6) + (7) - (8) + (11) - (26) + (27)$
8	$0 = +0{\cdot}87 - (4) + (5) + (13) - (17) - (28) + (29)$
9	$0 = -1{\cdot}95 - (16) + (17) - (20) + (21) - (29) + (30)$
10	$0 = -1{\cdot}92 - (19) + (20) - (30) + (31) - (34) + (35)$
11	$0 = -1{\cdot}46 - (18) + (19) - (35) + (36) - (38) + (39)$
12	$0 = +2{\cdot}35 - (31) + (32) - (33) + (34) - (40) + (41)$
13	$0 = -0{\cdot}68 + (33) - (36) - (37) + (38) - (41) + (42)$
14	$0 = -10 + 47{\cdot}4(18) - 81{\cdot}0(19) + 33{\cdot}6(20) + 14{\cdot}3(30) - 29{\cdot}4(31) + 15{\cdot}1(32) + 6{\cdot}3(37) - 31{\cdot}3(38) + 25{\cdot}0(39) + 28{\cdot}5(40) - 50{\cdot}6(41) + 22{\cdot}1(42)$
15	$0 = -84 + 14{\cdot}5(1) - 34{\cdot}7(3) - 40{\cdot}5(4) + 32{\cdot}5(5) + 29{\cdot}1(9) - 29{\cdot}8(10) + 0{\cdot}7(12) + 15{\cdot}1(20) - 17{\cdot}3(21) + 2{\cdot}2(23) + 26{\cdot}6(28) - 56{\cdot}0(29) + 29{\cdot}4(30)$
16	$0 = +155 + 20{\cdot}8(1) - 35{\cdot}3(2) + 14{\cdot}5(3) + 28{\cdot}4(14) - 40{\cdot}5(15) + 12{\cdot}1(16) + 2{\cdot}2(21) - 44{\cdot}8(22) + 42{\cdot}1(23)$
17	$0 = +142 - 8{\cdot}0(4) + 15{\cdot}0(6) - 0{\cdot}7(10) + 4{\cdot}6(11) - 3{\cdot}9(12) - 10{\cdot}0(13) + 38{\cdot}4(14) - 28{\cdot}4(15)$
18	$0 = +46 - 16{\cdot}4(1) + 35{\cdot}3(2) + 30{\cdot}0(6) - 15{\cdot}0(7) + 44{\cdot}8(22) - 56{\cdot}0(23) + 11{\cdot}2(24) + 2{\cdot}5(25) - 21{\cdot}8(26) + 19{\cdot}3(27)$

(*c*) *Figure adjustment*—Continued.

Correlate equations, part (*r*).

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
(1	−1		−1		−1						
(2)				−1	+1						
(3)		−1	+1	+1							
(4)		+1						−1			
(5)	...	...	...	...	...	...	...	+1	...	...	...
(6)	+1						−1				
(7)							+1				
(8)						−1	−1				
(9)					−1	+1					
(10)	...	...	−1	...	...	...	...	...	...	...	...
(11)	−1						+1				
(12)	+1		+1		+1						
(13)		−1						+1			
(14)		+1	−1	−1							
(15)	...	...	+1	...	...	...	...	...	...	...	...
(16)				+1					−1		
(17)								−1	+1		
(18)											−1
(19)										−1	+1
(20)	...	...	..	...	...	...	...	...	−1	+1	...
(21)				−1					+1		
(22)				+1	−1						
(23)					+1	−1					
(24)						+1					
(25)	...	...	...	...	...	−1	...	...	...	...	...
(26)							−1				
(27)						+1	+1				
(28)								−1			
(29)								+1	−1		
(30)	...	...	...	...	...	...	...	...	+1	−1	...
(31)										+1	
(32)											
(33)											
(34)										−1	
(35)	...	...	...	...	...	...	...	...	...	+1	−1
(36)											+1
(37)											
(38)											−1
(39)											+1

(*c*) *Figure adjustment*—Continued.

Correlate equations, part (*1*)—Completed.

Corrections.	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
(1)				+14·5	+20·8		−16·4
(2)					−35·3		+35·3
(3)				−34·7	+14·5		
(4)				−40·5		− 8·0	
(5)	...	...	......	+32·5	......	......	......
(6)						+15·0	+30·0
(7)							−15·0
(8)							
(9)				+29·1			
(10)	...	...	......	−29·8	......	− 0·7	......
(11)						+ 4·6	
(12)				+ 0·7		− 3·9	
(13)						−10·0	
(14)					+28·4	+38·4	
(15)	...	...	......	......	−40·5	−28·4	......
(16)					+12·1		
(17)							
(18)			+47·4				
(19)			−81·0				
(20)	...	...	+33·6	+15·1	.....	......	......
(21)				−17·3	+ 2·2		
(22)					−44·8		+44·8
(23)				+ 2·2	+42·6		−56·0
(24)							+11·2
(25)	...	...	......	......	......	......	+ 2·5
(26)							−21·8
(27)							+19·3
(28)				+26·6			
(29)				−56·0			
(30)	...	...	+14·3	+29·4	......	......	......
(31)	−1		−29·4				
(32)	+1		+15·1				
(33)	−1	+1					
(34)	+1						
(35)	...	...	......	......	......	......	......
(36)		−1					
(37)		−1	+ 6·3				
(38)		+1	−31·3				
(39)			+25·0				
(40)	−1	...	+28·5	......	......	......	......
(41)	+1	−1	−50·6				
(42)		+1	+22·1				

(*c*) *Figure adjustment*—Continued.

Normal equations, part (*1*).

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
+ 1·41	+4		+2		+2		−2				
− 0·03		+4	−2	−2				−2			
− 2·68			+6	+2	+2						
− 3·06				+6	−2				−2		
+ 2·37	...	...	...	...	+6	−2	...	...	...	...	...
+ 0·39						+6	+2				
+ 0·07							+6				
+ 0·87								+6	−2		
− 1·95									+6	−2	
− 1·92	...	...	...	...	...	...	...	...	...	+6	−2
− 1·46											+6

Normal equations, part (*1*)—Completed.

	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
+ 1·41				−13·8	−20·8	+6·5	+46·4
− 0·03				− 5·8	+13·9	+40·4	
− 2·68				−18·7	−75·2	−70·0	+16·4
− 3·06				−17·4	−13·5	−38·4	+9·5
+ 2·37	...	...	....	−40·7	+31·3	− 3·9	−49·1
+ 0·39				+26·9	−42·6		+84·0
+ 0·07						−10·4	−3·9
+ 0·87				−9·6		−2·0	
− 1·95			−19·3	+53·0	−9·9		
− 1·92	−2	...	+70·9	−14·3	...	....	....
− 1·46		−2	−72·1				
0=+ 2·35	+6	−2	−34·6				
− 0·68		+6	+35·1				
− 10			+16 738·98	+927·78			
− 84	...	...	....	+11 086·24	−145·89	+342·13	−361·00
+155					+8 308·84	+2 240·76	−5 979·85
+142						+2 706·98	+450·00
+ 46							+8 762·51

Resulting values of correlates and of corrections to angular directions:

		$''$	$''$	$''$
$C_1=-0.385\ 2$	$C_{10}=+1.001\ 4$	$(1)=+0.175$	$(15)=+1.853$	$(29)=-0.854$
$C_2=+1.425\ 1$	$C_{11}=+0.697\ 2$	$(2)=-0.885$	$(16)=-0.236$	$(30)=+0.415$
$C_3=-0.079\ 5$	$C_{12}=+0.063\ 6$	$(3)=-0.788$	$(17)=+0.491$	$(31)=+0.944$
$C_4=+1.253\ 3$	$C_{13}=+0.368\ 2$	$(4)=+0.725$	$(18)=-0.708$	$(32)=+0.060$
$C_5=+0.220\ 7$	$C_{14}=-0.000\ 224$	$(5)=+0.948$	$(19)=-0.286$	$(33)=+0.305$
$C_6=+0.158\ 9$	$C_{15}=+0.006\ 482$	$(6)=-1.196$	$(20)=-0.137$	$(34)=-0.938$
$C_7=-0.269\ 1$	$C_{16}=-0.021\ 500$	$(7)=-0.009$	$(21)=-0.184$	$(35)=+0.304$
$C_8=+0.737\ 6$	$C_{17}=-0.037\ 392$	$(8)=+0.110$	$(22)=+1.220$	$(36)=+0.329$
$C_9=+1.229\ 0$	$C_{18}=-0.017\ 312$	$(9)=+0.127$	$(23)=+0.130$	$(37)=-0.370$
		$(10)=-0.088$	$(24)=-0.035$	$(38)=-0.322$
		$(11)=-0.056$	$(25)=-0.202$	$(39)=+0.692$
		$(12)=-0.094$	$(26)=+0.646$	$(40)=-0.070$
		$(13)=-0.314$	$(27)=-0.444$	$(41)=-0.293$
		$(14)=-1.795$	$(28)=-0.565$	$(42)=+0.363$

(*c*) *Figure adjustment.*

Observation equations of section (2).

No.	
1	$0=+1.73-(1)+(3)-(9)+(10)$
2	$0=+2.91-(2)+(4)-(11)+(12)$
3	$0=+2.53-(25)+(26)-(27)+(29)-(32)+(33)$
4	$0=-5.24-(5)+(8)-(13)+(14)-(20)+(21)$
5	$0=-3.18-(18)+(19)-(24)+(25)-(29)+(30)$
6	$0=-0.91-(15)+(17)+(22)-(26)-(31)+(32)$
7	$0=+2.81-(15)+(16)+(22)-(25)-(28)+(29)$
8	$0=-0.56-(5)+(7)-(19)+(21)-(23)+(24)$
9	$0=-3.28-(7)+(8)-(13)+(15)-(22)+(23)$
10	$0=+0.76-(3)+(4)-(8)+(9)-(11)+(13)$
11	$0=+15+31.6(1)-44.8(2)-45.0(3)+25.8(4)+8.9(8)-33.3(9)+24.4(10)+29.7(11)$ $-56.1(12)+26.4(13)$
12	$0=-204+24.6(5)-58.8(7)+34.2(8)+13.4(13)-28.1(14)+14.7(15)+20.7(19)-38.1(20)$ $+17.4(21)+29.2(22)-51.3(23)+22.1(24)$
13	$0=+257+124.6(15)-146.2(16)+21.6(17)+2.9(27)-112.5(28)+109.6(29)+30.9(31)$ $-57.7(32)+26.8(33)$
14	$0=-384+14.7(14)-160.9(15)+146.2(16)+47.8(18)-68.5(19)+20.7(20)+112.5(28)$ $-140.7(29)-28.2(30)$
15	$0=+274+24.6(5)-333.2(6)+308.6(7)+47.8(18)-45.6(19)-2.2(21)-100.6(23)$ $+100.6(25)-28.2(29)+28.2(30)$

(c) *Figure adjustment*—Continued.

Correlate equations, part (2).

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
(1)	−1										+31·6				
(2)		−1									−44·8				
(3)	+1									−1	−45·0				
(4)		+1								+1	+25·8				
(5)	....	....	....	−1	....	....	....	−1	....	....	....	+24·6	....	....	+24·6
(6)															−333·2
(7)								+1	−1			−58·8			+308·6
(8)				+1					+1	−1	+8·9	+34·2			
(9)	−1									+1	−33·3				
(10)	+1	....	....	....	....	....	....	....	....	....	+24·4	....	....	....	....
(11)		−1								−1	+29·7				
(12)		+1									−56·1				
(13)				−1					−1	+1	+26·4	+13·4			
(14)				+1								−28·1		+14·7	
(15)	....	....	....	....	....	−1	−1	....	+1	....	....	+14·7	+124·6	−160·9	
(16)							+1						−146·2	+146·2	
(17)						+1							+21·6		
(18)					−1									+47·8	+47·8
(19)					+1			−1				+20·7		−68·5	−45·6
(20)	....	....	....	−1	....	....	....	....	....	....	....	−38·1	....	+20·7	....
(21)				+1				+1				+17·4			−2·2
(22)						+1	+1		−1			+29·2			
(23)								−1	+1			−51·3			−100·6
(24)					−1			+1				+22·1			
(25)	....	....	−1	....	+1	....	−1	....	....	....	....	....	....	....	+100·6
(26)			+1			−1									
(27)			−1										+2·9		
(28)							−1						−112·5	+112·5	
(29)			+1		−1		+1						+109·6	−140·7	−28·2
(30)	....	....	....	....	+1	....	....	....	....	....	....	....	....	+28·2	+28·2
(31)						−1							+30·9		
(32)			−1			+1							−57·7		
(33)			+1										+26·8		

Normal equations, part (2).

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
0 = + 1·73	+4									−2	−18·9				
+ 2·91		+4								+2	−15·2				
+ 2·53			+6		−2	−2	+2						+191·2	−140·7	−128·8
− 5·24				+6				+2	+2	−2	−17·5	+23·6		−6·0	−26·8
− 3·18	...	...	...	...	+6	...	−2	−2	...	...	....	−1·4	−109·6	+52·6	+63·6
− 0·91						+6	+2		−2			+14·5	−191·6	+160·9	
+ 2·81							+6		−2			+14·5	−48·7	+53·9	−128·8
− 0·56								+6	−2			−13·3		+68·5	+428·0
− 3·28									+6	−2	−17·5	+13·8	+124·6	−160·9	−409·2
+ 0·76	...	...	...	...	...	...	...	...	...	+6	+25·3	−20·8	....	....	....
+ 15											+12 205·96	+658·14			
−204												+12 573·10	+1 831·62	−4 984·92	−13 361·94
+257													+67 045·32	−69 499·55	−3 096·72
−384														+88 132·90	+10 171·42
+274	...	...	...	...	...	...	...	...	...	...	....	....	....	....	+233 061·60

Resulting values of correlates and of corrections to angular directions.

Correlates (″)	Corrections (″)	Corrections (″)
$C_1 = +0.002$	(1) = −0.104	(18) = +0.182
C_2 −1.186 5	(2) = +1.336	(19) = −0.237
C_3 −0.041 667	(3) = −0.744	(20) = −1.215
C_4 +0.762 67	(4) = −0.380	(21) = +1.269
C_5 +0.594 30	(5) = −0.400	(22) = −0.034
C_6 +0.413 14	(6) = −0.165	(23) = −0.394
C_7 −1.876 6	(7) = −1.752	(24) = +0.009
C_8 +0.152 44	(8) = +1.394	(25) = +0.873
C_9 +0.855 46	(9) = +1.006	(26) = −0.455
C_{10} +0.892 72	(10) = −0.084	(27) = +0.078
C_{11} −0.003 340	(11) = +0.195	(28) = +0.553
C_{12} +0.020 420	(12) = −0.999	(29) = −1.683
C_{13} +0.012 498	(13) = −0.540	(30) = +1.052
C_{14} −0.015 745	(14) = +0.420	(31) = −0.027
$C_{15} = -0.000\ 494\ 4$	(15) = −0.046	(32) = −0.266
	(16) = +0.287	(33) = +0.293
	(17) = +0.683	

(*d*) *Adjusted triangles, Maryland, Delaware, and New Jersey.*

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
1	Osbornes Ruin	77	29	15.76	−0.04	15.72	0.37	4.419 418 8	26 267.50
	Pooles Island	54	27	12.11	−1.20	10.91	0.36	4.340 289 4	21 892.20
	Finlay	48	03	34.63	−0.17	34.46	0.36	4.301 337 0	20 014.14
				02.50			1.09		
2	Clough	64	34	15.72	−1.48	14.24	0.79	4.550 316 3	35 507.19
	Linstid	69	13	07.03	+0.72	07.75	0.80	4.565 358 1	36 758.53
	Finlay	46	12	39.61	+0.79	40.40	0.80	4.453 046 8	28 382.25
				02.36			2.39		
3	Clough	36	31	42.55	+3.65	46.20	0.56	4.340 289 4	21 892.20
	Finlay	55	23	20.93	−0.96	19.97	0.56	4.481 014 2	30 270.12
	Osbornes Ruin	88	04	55.52	−0.01	55.51	0.56	4.565 358 0	36 758.52
				59.00			1.68		
4	Still Pond	58	52	00.65	+1.40	02.05	0.55	4.565 358 0	36 758.52
	Clough	96	33	18.97	+1.56	20.53	0.56	4.630 050 5	42 662.91
	Finlay	24	34	38.98	+0.10	39.08	0.55	4.251 910 9	17 861.21
				58.60			1.66		
5	Still Pond	84	02	19.46	+0.31	19.77	0.39	4.481 014 2	30 270.12
	Clough	60	01	36.42	−2.09	34.33	0.40	4.421 013 9	26 364.16
	Osbornes Ruin	35	56	07.30	−0.21	07.09	0.40	4.251 910 9	17 861.21
				03.18			1.19		

(*d*) *Adjusted triangles, Maryland, Delaware, and New Jersey*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
6	Still Pond	25	10	18·81	−1·09	17·72	0·40	4·340 289 4	21 892·26
	Finlay	30	48	41·95	−1·06	40·89	0·40	4·421 013 9	26 364·10
	Osbornes Ruin	124	01	02·82	−0·22	02·60	0·41	4·630 050 5	42 662·91
				03·58			1·21		
7	Turkey Point	83	04	49·89	−0·24	49·65	0·30	4·421 013 9	26 364·16
	Still Pond	61	59	40·93	−0·17	40·76	0·30	4·370 101 9	23 447·79
	Osbornes Ruin	34	55	30·47	+0·02	30·49	0·30	4·181 967 8	15 204·35
				01·29			0·90		
8	Turkey Point	44	01	48·72	−1·09	47·63	0·39	4·301 337 0	20 014·14
	Pooles Island	54	30	55·00	+1·19	56·19	0·39	4·370 101 8	23 447·78
	Osbornes Ruin	81	27	17·53	−0·17	17·36	0·40	4·454 483 8	28 476·32
				01·25			1·18		
9	Hope	38	17	06·79	−0·29	06·50	0·57	4·453 046 8	28 382·25
	Linstid	32	54	15·37	+0·22	15·59	0·57	4·395 942 3	24 885·27
	Clough	108	48	40·41	−0·80	39·61	0·56	4·637 115 2	43 362·59
				02·57			1·70		
10	Hope	35	38	49·44	+1·27	50·71	0·38	4·251 910 9	17 861·21
	Clough	90	03	44·90	+0·73	45·63	0·37	4·486 395 3	30 647·52
	Still Pond	54	17	24·84	−0·05	24·79	0·38	4·395 942 5	24 885·28
				59·18			1·13		
11	Barclay	92	00	29·81	+1·24	31·05	0·35	4·486 395 3	30 647·52
	Hope	55	54	38·82	+0·53	39·35	0·35	4·404 779 8	25 396·85
	Still Pond	32	04	50·50	+0·15	50·65	0·35	4·211 848 5	16 287·28
				59·13			1·05		
12	Hartly	40	03	50·76	+1·01	51·77	0·31	4·404 779 8	25 396·85
	Barclay	115	57	00·02	+0·03	00·05	0·31	4·549 977 2	35 479·48
	Still Pond	23	59	08·69	+0·42	09·11	0·31	4·205 203 2	16 039·96
				59·47			0·93		
13	Kent	36	29	56·34	−0·22	56·12	0·31	4·211 848 5	16 287·28
	Hope	54	27	29·59	−0·89	28·70	0·31	4·347 931 0	22 280·81
	Barclay	89	02	37·34	−1·24	36·10	0·30	4·437 412 3	27 378·67
				03·27			0·92		
14	Kent	43	37	02·70	+0·66	03·36	0·27	4·205 203 2	16 039·96
	Barclay	62	59	52·83	−0·03	52·80	0·27	4·316 327 1	20 717·01
	Hartly	73	23	04·60	+0·05	04·65	0·27	4·347 931 0	22 280·81
				00·13			0·81		

(*d*) *Adjusted triangles, Maryland, Delaware, and New Jersey*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
15	Mahon	40	47	24·62	−1·09	23·53	0·41	4·316 327 1	20 717·01
	Kent	47	34	08·20	−0·74	07·46	0·41	4·369 331 2	23 406·22
	Hartly	91	38	30·14	+0·10	30·24	0·41	4·501 046 0	31 699·03
				02·96			1·23		
16	Stone	35	19	31·55	−1·19	30·36	0·53	4·316 327 1	20 717·01
	Kent	86	42	27·32	−0·38	26·94	0·53	4·553 521 7	35 770·23
	Hartly	57	58	05·63	−1·34	04·29	0·53	4·482 506 7	30 374·33
				04·50			1·59		
17	Stone	73	51	59·84	−0·73	59·11	0·51	4·501 046 0	31 699·03
	Kent	39	08	19·12	+0·36	19·48	0·52	4·318 662 2	20 828·70
	Mahon	66	59	43·34	−0·39	42·95	0·51	4·482 506 7	30 374·33
				02·30			1·54		
18	Stone	38	32	28·29	+0·46	28·75	0·39	4·369 331 2	23 406·22
	Hartly	33	40	24·51	+1·44	25·95	0·39	4·318 662 2	20 828·70
	Mahon	107	47	07·96	−1·48	06·48	0·40	4·553 521 6	35 770·22
				00·76			1·18		
19	Egg Island L. H.	50	22	38·02	+2·48	40·50	0·38	4·318 662 2	20 828·70
	Stone	57	26	08·11	+0·96	09·07	0·39	4·357 739 8	22 789·76
	Mahon	72	11	09·78	+1·80	11·58	0·38	4·410 684 3	25 744·49
				55·91			1·15		
20	Brandywine Shoal L. H.	35	47	01·21	−0·36	00·85	0·30	4·318 662 2	20 828·70
	Stone	112	35	31·90	+0·49	32·39	0·31	4·517 036 5	32 887·92
	Mahon	31	37	24·52	+3·15	27·67	0·30	4·271 329 9	18 677·98
				57·63			0·91		
21	Brandywine Shoal L. H.	79	21	38·79	+0·05	38·84	0·34	4·410 684 3	25 744·49
	Stone	55	09	23·79	−0·47	23·32	0·33	4·332 407 3	21 498·46
	Egg Island L. H.	45	28	59·82	−0·98	58·84	0·33	4·271 330 0	18 677·98
				02·40			1·00		
22	Brandywine Shoal L. H.	43	34	37·58	+0·40	37·98	0·41	4·357 739 8	22 789·76
	Mahon	40	33	45·26	−2·35	43·91	0·42	4·332 407 4	21 498·46
	Egg Island L. H.	95	51	37·84	+1·51	39·35	0·41	4·517 036 5	32 887·92
				00·68			1·24		
23	Cape May L. H.	10	35	51·90	−2·24	49·66	0·07	4·271 329 9	18 677·98
	Stone	8	11	43·72	+0·33	44·05	0·07	4·160 717 5	14 478·30
	Brandywine Shoal L. H.	161	12	27·41	−0·90	26·51	0·08	4·514 794 6	32 718·60
				03·03			0·22		

(*d*) *Adjusted triangles, Maryland, Delaware, and New Jersey*—Completed.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
24	Cape May L. H.	22	24	....	....	54·83	0·50	4·318 662 2	20 828·70
	Stone	120	47	15·62	+0·83	16·45	0·49	4·671 407 7	46 925·37
	Mahon	36	47	48·65	+1·56	50·21	0·50	4·514 794 6	32 718·60
							1·49		
25	Cape May L. H.	47	22	55·58	+0·50	56·08	0·64	4·410 684 3	25 744·49
	Stone	63	21	07·51	−0·13	07·38	0·63	4·495 103 8	31 268·27
	Egg Island L. H.	69	15	59·85	−1·40	58·45	0·64	4·514 794 7	32 718·60
				02·94			1·91		
26	Cape May L. H.	11	49	....	....	05·16	0·12	4·517 036 5	32 837·92
	Brandywine Shoal L. H.	163	00	31·38	+1·27	32·65	0·11	4·671 407 8	46 925·38
	Mahon	5	10	24·13	−1·59	22·54	0·12	4·160 717 4	14 478·29
							0·35		
27	Cape May L. H.	36	47	03·68	+2·74	06·42	0·23	4·332 407 3	21 498·46
	Brandywine Shoal L. H.	119	25	53·80	+0·86	54·66	0·23	4·495 103 7	31 268·26
	Egg Island L. H.	23	46	60·03	−0·42	59·61	0·23	4·160 717 5	14 478·30
				57·51			0·69		
28	Cape May L. H.	24	58	....	....	01·25	0·52	4·357 739 8	22 789·76
	Mahon	35	23	21·13	+0·23	21·36	0·53	4·495 103 8	31 268·27
	Egg Island L. H.	119	38	37·87	+1·09	38·96	0·52	4·671 407 9	46 925·39
							1·57		
29	Cape Henlopen L. H.	34	13	26·27	−0·24	26·03	0·36	4·271 329 9	18 677·98
	Stone	44	20	32·22	+0·73	32·95	0·36	4·365 706 6	23 211·67
	Brandywine Shoal L. H.	101	26	01·68	+0·42	02·10	0·36	4·512 558 4	32 550·56
				00·17			1·08		
30	Cape Henlopen L. H.	72	22	43·32	+0·32	43·64	0·53	4·514 794 6	32 718·60
	Stone	36	08	48·50	+0·39	48·89	0·53	4·306 412 0	20 249·39
	Cape May L. H.	71	28	28·59	+0·47	29·06	0·53	4·512 558 3	32 550·55
				00·41			1·59		
31	Cape Henlopen L. H.	38	09	17·05	+0·56	17·61	0·25	4·160 717 5	14 478·30
	Brandywine Shoal L. H.	59	46	25·73	−1·33	24·40	0·25	4·306 412 0	20 249·39
	Cape May L. H.	82	04	20·49	−1·76	18·73	0·24	4·365 706 6	23 211·67
				03·27			0·74		

(*e*) *The precision of the Eastern Shore series of triangles.*

For a fair estimate of the precision of the adjusted triangulation, we have in the first place the mean error of an observed angle (of unit weight), as derived from 75 corrections to directions contained in the series and involving 33 conditions—

$$m = \sqrt{\frac{2 \times 37{\cdot}895}{33}} = \pm 1''{\cdot}515$$

To get the probable error of the side Still Pond to Hope, we start form the line Finlay to Linstid and reach the side Still Pond to Hope via Clough by three triangles. For this part we have $\delta_{a_n} = 14{\cdot}1$ and $\Sigma(\delta^2_A + \delta_A\,\delta_B + \delta^2_B) = 36{\cdot}3$. Hence, $u_{a_n} = 0{\cdot}1217$, $m_{a_n} = \pm 0{\cdot}529$ and probable error of side $= \pm 0{\cdot}357$ metre.

Similarly for the line Hartly to Kent we have $\delta_{a_n} = 20{\cdot}9$, $\Sigma(\ldots) = 64{\cdot}2$, $u_{a_n} = 0{\cdot}098\,0$, $m_{a_n} = \pm 0{\cdot}474$ and probable error of side $= \pm 0{\cdot}320$ metre.

Also for the terminal side Cape May Light to Cape Henlopen Light, $\delta_{a_n} = 21{\cdot}4$, $\Sigma(\ldots) = 111{\cdot}7$, $u_{a_n} = 0{\cdot}162\,7$, $m_{a_n} = \pm 0{\cdot}611$ and probable error of side $= \pm 0{\cdot}412$ metre.

To the above probable errors we have yet to add the part depending on the probable error of the initial side Finlay to Linstid ($\pm 0{\cdot}33$ metre) in proportion to the length of the sides, viz: $\pm 0{\cdot}285$, $\pm 0{\cdot}19$, and $\pm 0{\cdot}19$ metre, respectively.

Probable error of length of side Still Pond to Hope $= \pm 0{\cdot}357 \pm 0{\cdot}285 = \pm 0{\cdot}457$ metre $= \frac{1}{67\,100}$ part of the length.

Probable error of length of side Hartly to Kent $= \pm 0{\cdot}320 \pm 0{\cdot}19 = \pm 0{\cdot}372$ metre $= \frac{1}{55\,700}$ part of the length.

Probable error of length of side Cape May Light to Cape Henlopen Light $= \pm 0{\cdot}412 \pm 0{\cdot}19 = \pm 0{\cdot}454$ metre $= \frac{1}{44\,600}$ part of the length.

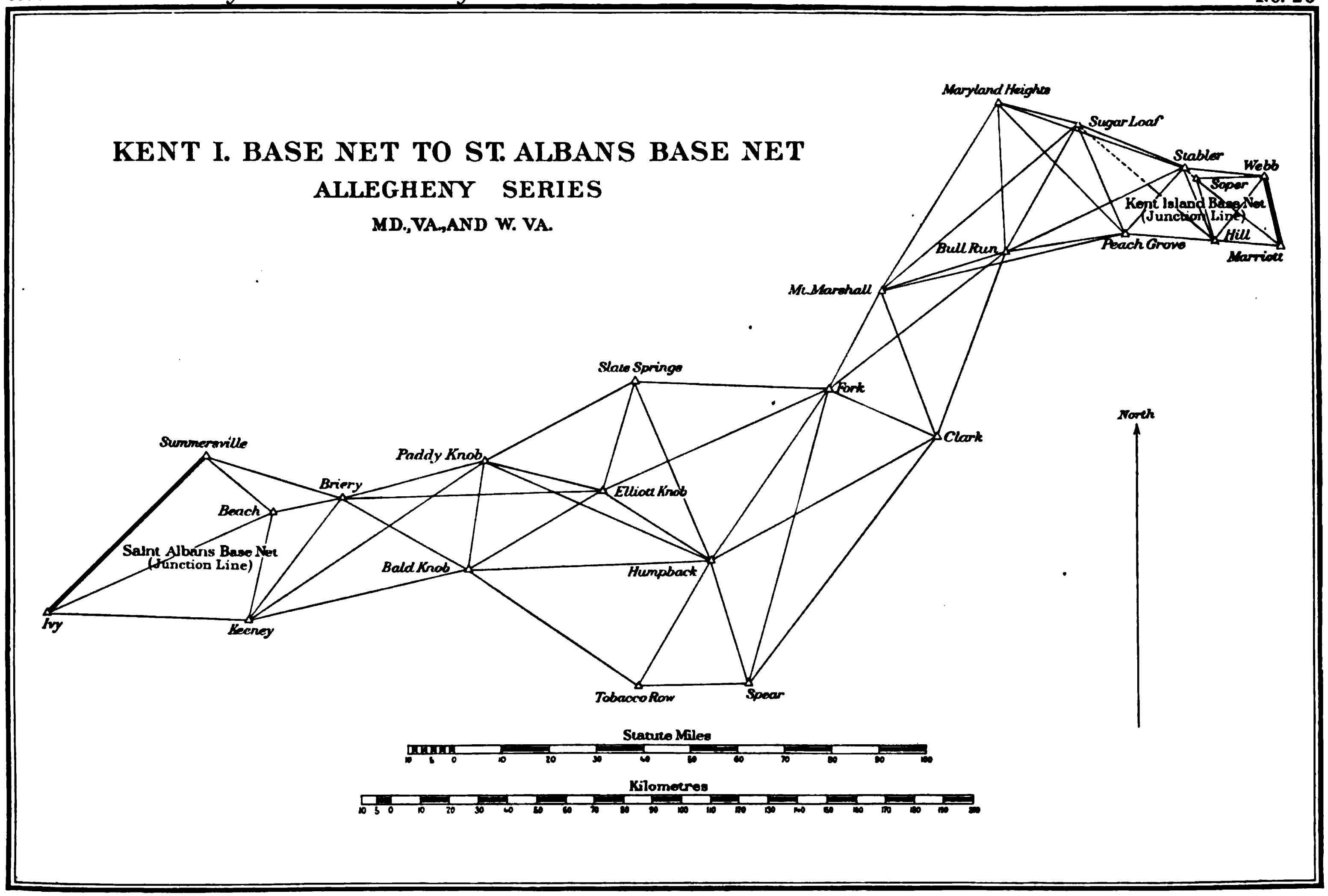
The distance between the middle points of the lines Finlay to Linstid and Still Pond to Hope when projected on the Thirty-ninth parallel is about 42 kilometres (26 statute miles), from Still Pond—Hope to Hartly—Kent is about 29·5 kilometres (18 statute miles), and from Hartly—Kent to Cape May Light—Cape Henlopen Light is about 56·5 kilometres (35 statute miles).

The average probable error for the first part of the triangulation may be taken as $\frac{1}{2}\left(\frac{1}{107\,600} + \frac{1}{67\,100}\right) = \frac{1}{82\,600}$ or 0·5 metre; for the second part $\frac{1}{2}\left(\frac{1}{67\,100} + \frac{1}{55\,700}\right) = \frac{1}{60\,900}$ or 0·5 metre, and for the third part $\frac{1}{2}\left(\frac{1}{55\,700} + \frac{1}{44\,600}\right) = \frac{1}{49\,600}$ or 1·1 metres; total for the Eastern Shore series, 2·1 metres.

(2) THE ALLEGHENY SERIES OF TRIANGLES, 1846–1850 AND 1868–1880.

(*a*) *Introduction.*

The triangulation which extends from the Kent Island Base, Maryland, to the St. Albans Base, West Virginia, is made up in part of the older work (antedating the transcontinental chain) from the Kent Base to the Blue Ridge, which branch was executed between the years 1846 and 1874 (with one interpolated station in 1879), and in part of the new branch or southern and western extension dating between 1874–1880.


KENT I. BASE NET TO ST. ALBANS BASE NET
ALLEGHENY SERIES
MD., VA., AND W. VA.
Maryland Heights
Sugar Loaf
Stabler
Webb
Soper
Kent Island Base Net
(Junction Line)
Hill
Marriott
Peach Grove
Bull Run
Mt. Marshall
Slate Springs
Fork
Clark
North
Summersville
Paddy Knob
Briery
Elliott Knob
Beach
Saint Albans Base Net
(Junction Line)
Bald Knob
Humpback
Ivy
Keeney
Tobacco Row
Spear
Statute Miles
Kilometres

The principal observers of the old triangulation were A. D. Bache, Superintendent, and C. O. Boutelle, Assistant, and of the later extension A. T. Mosman, Assistant. The total extent between the two base-net sides and measured along the middle of the triangulation is about 545 kilometres or 339 statute miles. The central station Humpback, Virginia, is a prominent point in the arc of the parallel of 39° as well as in the oblique arc of the Atlantic and Gulf.

The following description of the country traversed by the connecting triangulation with remarks on the latter was furnished by Assistant Mosman:

The section starts from Kent Island on Chesapeake Bay and traverses the rolling country to the Blue Ridge and then proceeds nearly west through the Allegheny Mountains, covering the Kanawha River Valley, in which is located the St. Albans base line. The country near Chesapeake Bay is partially wooded, with considerable cultivated land. The summits about the stations on the Blue Ridge are between 1 000 and 3 500 feet of elevation, and on the North Mountain and the main Alleghenies reach 4 000 feet and over, the highest station, Briery, being 1 379 metres or 4 524 feet above the sea. Nearly all the summits are wooded and the country is very sparsely inhabited. The roads are few and transportation difficult. In some cases it was necessary to travel 80 to 100 miles to move camp between stations only 50 miles apart.

No high signals were necessary in this section and poles with lozenge-shaped targets* could usually be seen up to 56 kilometres (35 statute miles, about), beyond which heliotropes were used. On the Blue Ridge and the Alleghenies the stations are generally marked by bolts in rock ledges, and in soil by a cone sunk 3 feet under ground, over which was placed a marble post with cross lines for center; there are also spikes driven into cement for reference posts about 6 feet from the central mark.

Assistant Boutelle generally used the large theodolite in 7 positions with 6 to 18 series, whereas Assistant Mosman with the 50-centimetre theodolite adhered to 11 positions of the circle with 3 series in each, and when using the 30-centimetre theodolite, adopted 17 positions with 2 series in each.

A critical examination of the internal complexity of lines in the eastern part of the triangulation, between sides Webb-Marriott and Mount Marshall-Bull Run, renders it highly probable that no great error could accumulate in this branch of the connection. Advantage has been taken of this circumstance to reduce considerably the number of equations to be solved simultaneously by treating the 22 conditions contained in this eastern part as if there was no discrepancy between the base nets, and throwing the last condition for accord of bases on the second or western part, which still requires the establishment and solution of 33 equations.

The discrepancy between the bases is very small.

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* These poles were 4 centimetres square in cross section and about 6 metres high, with alternate strips of white and black muslin and surmounted by a white muslin target with sides of 1 metre.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments* (*eastern part*).

Webb, Anne Arundel County, Maryland. July 10 to August 14, 1848. 60-centimetre theodolite, No. 2. A. D. Bache, observer. October 21 to December 2, 1850. 75-centimetre theodolite, No. 1. A. D. Bache, observer. September 18 to September 25, 1868. 75-centimetre theodolite, No. 1. C. O. Boutelle, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Linstid	0	00	00·00	±0·08	−0·02		59·98
	Marriott	76	16	06·19	0·12	+0·25		06·44
3	Hill	129	26	58·53	0·15		0·00	58·53
4	Soper	178	32	04·72	0·08		0·00	04·72
5	Stable	186	55	11·56	0·14		−0·02	11·54
	Azimuth Mark	275	40	01·37	0·11			
	Finlay	289	44	43·01	0·22	−0·23		42·78
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·94.

Marriott, Anne Arundel County, Maryland. November 18 to December 9, 1846. 30-centimetre theodolite, No. 11. E. Blunt, observer. May 18 to June 18, 1849. 60-centimetre theodolite, No. 2. A. D. Bache, observer.

		°	′	″	″	″	″	″
1	Hill	0	00	00·00	*±0·15		−0·29	59·71
2	Soper	32	06	10·36			+0·38	10·74
	Webb	70	08	37·17		−0·24		36·93
	Azimuth Mark	82	23	48·68	†0·17			
	Linstid	107	33	48·30		+0·34		48·64
	Taylor	125	56	32·84		−0·20		32·64
	Kent Island North Base	147	53	16·80		−0·10		16·70
	Kent Island South Base	166	06	54·12	*0·10	+0·19		54·31
	Poplar Island	206	58	03·32	*0·12			
	Blake	248	21	51·62	*0·19			
					Mean	0·00		

Probable error of a single observation of a direction— (6 *D.* and 6 *R.*) = ± 0″·67 in 1846.
(*D.* and *R.*) = ± 1″·10 in 1849.

* 1846. † 1849.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments* (*eastern part*)—Continued.

Hill, Prince George County, Maryland. June 18 to July 15, 1846. 60-centimetre theodolite, No. 2. A. D. Bache, observer. August 8 to October 4, 1850. 75-centimetre theodolite, No. 1. A. D. Bache and A. A. Humphreys, observers. October 9 to November 12, 1868. 75-centimetre theodolite, No. 1. Telescope above ground 16·76 metres in 1868. C. O. Boutelle, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
6	Peach Grove	0	00	00·00	±0·11	−0·30	59·70
	Causten	5	54	28·96	0·06		
	Soldiers' Home, lightning rod near center of tower	18	14	54·48	0·25		
	Montgomery Blair's house, center of cupola	29	46	29·51	0·33		
7	Sugar Loaf	37	48	42·47	0·10	+0·10	42·57
8	Stabler	65	16	57·50	0·10	+0·20	57·70
9	Soper	69	14	40·71	0·07	−0·31	40·40
	Azimuth Mark	125	08	23·97	0·10		
10	Webb	125	08	24·12	0·10	+0·12	24·24
11	Marriott	181	48	56·12	0·07	+0·20	56·32
	Theological Seminary (new) cross	330	08	02·81	0·56		
	Theological Seminary (old)	330	09	58·44	0·16		
	High School	331	31	08·62	0·13		
	Coast Survey Office (old) chimney	348	20	52·43	0·17		
	United States Capitol, head of Statue of Liberty	350	24	27·16	0·20		
	Seaton	350	58	47·36	0·09		
	United States Naval Observatory (old), station east of dome	353	54	50·38	0·20		
	Georgetown College Observatory, center of dome	359	02	16·10	0·18		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·90.

Soper, Montgomery County, Maryland. June 19 to July 23, 1850. 75-centimetre theodolite, No. 1. A. D. Bache, observer.

		°	′	″	″	″	″
12	Webb	0	00	00·00	±0·11	−0·08	59·92
13	Marriott	39	41	37·08	0·13	−0·17	36·91
14	Hill	75	01	10·92	0·14	+0·24	11·16
	Azimuth Mark	89	30	15·00	0·22		
	Causten	122	09	57·30	0·13		
	Stabler	233	17				09·98

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·91.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments* (*eastern part*)—Continued.

Stabler, Montgomery County, Maryland. July 17 to September 3, 1869. 75-centimetre theodolite, No. 1. Telescope above ground 16·76 metres. C. O. Boutelle, observer.

No. of direction.	Objects observed.	Resulting directions from stations adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
17	Hill	0	00	00·00	±0·10	−0·24	59·76
18	Peach Grove	63	40	03·06	0·14	−0·37	02·69
19	Bull Run	87	11	16·57	0·20	+0·04	16·61
20	Maryland Heights	131	27	54·59	0·21	+0·06	54·65
21	Sugar Loaf	134	09	42·34	0·17	+0·48	42·82
15	Webb	297	19	37·68	0·18	+0·01	37·69
16	Soper	342	13	41·17	0·21	0·00	41·17

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·08.

Peach Grove, Fairfax County, Virginia. October 11 to November 8, 1869. July 28 to August 15, 1870. 75-centimetre theodolite, No. 1. Telescope above ground 13·72 metres. C. O. Boutelle, observer.

No. of direction.	Objects observed.				Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
22	Mount Marshall	0	00	00·00	±0·20	−0·36	59·64
23	Bull Run	4	36	29·66	0·18	+0·18	29·84
24	Maryland Heights	58	32	34·06	0·21	−0·50	33·56
25	Sugar Loaf	79	59	52·76	0·10	+0·06	52·82
26	Stabler	143	47	23·85	0·18	+0·35	24·20
	Causten	187	26	02·78	0·14		
27	Hill	194	50	24·85	0·14	+0·27	25·12

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·02.

Sugar Loaf, Frederick County, Maryland. August 18 to November 19, 1879. 50-centimetre theodolite, No. 113. C. O. Boutelle, F. D. Granger, and J. B. Boutelle, observers.

No. of direction.	Objects observed.				Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
	Reference Mark, at Barnesville	0	00	00·00	±0·03		
30	Bull Run	45	27	15·79	0·06	+0·72	16·51
31	Mount Marshall	65	36	50·72	0·08	−0·11	50·61
32	Maryland Heights	120	27	54·38	0·11	+0·10	54·48
	Wolf	207	46	15·33	0·07		
	Granite	209	55	11·18	0·06		
28	Stabler	306	43	36·06	0·13	−0·46	35·60
	Hill	325	05				39·25
	Soldiers' Home	329	57	28·46	0·10		
	United States Capitol	335	03	39·45	0·28		
	Strecker	338	23	34·86	0·09		
	Theological Seminary (new) cross	344	51	10·37	0·19		
29	Peach Grove	352	26	27·18	0·12	−0·26	26·92

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·60.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments (eastern part)*—Completed.

Mount Marshall, Rappahannock County, Virginia. July 18 to September 7, 1874. 35-centimetre theodolite, No. 10. A. T. Mosman, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
	Fork	0	00	00·00	±0·11		
43	Maryland Heights	184	15	49·56	0·24	−0·26	49·30
44	Sugar Loaf	202	41	37·50	0·16	+0·36	37·86
45	Bull Run	225	17	06·78	0·17	+0·19	06·97
46	Peach Grove	229	31	29·99	0·16	−0·28	29·71
	View Tree	248	47	43·70	0·19		
	National Cemetery, flag	302	03	40·42	0·31		
	Culpeper Baptist Church spire	302	11	34·29	0·36		
	Clark	311	50	33·98	0·17		
	Peters	336	20	36·44	0·16		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·29.

Bull Run, Fauquier County, Virginia. September 22 to November 28, 1871. 75-centimetre theodolite No. 1. C. O. Boutelle, observer.

		°	′	″	″	″	″
	Azimuth Mark	0	00	00·00	±0·12		
	Clark	1	07	09·35	0·19		
	View Tree	13	44	29·24	0·08		
	Fork	33	03	17·51	0·18		
38	Mount Marshall	53	39	05·53	0·22	+0·11	05·64
	Paris	92	24	57·37	0·27		
39	Maryland Heights	157	20	07·15	0·24	+0·49	07·64
	Leesburg	179	01	37·56	0·30		
40	Sugar Loaf	190	54	06·98	0·21	−0·68	06·30
41	Stabler	225	12	03·95	0·15	+0·08	04·03
42	Peach Grove	242	29	57·85	0·18	0·00	57·85

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·09.

Maryland Heights, Washington County, Maryland. September 16 to October 28, 1870. 75-centimetre theodolite, No. 1. C. O. Boutelle, observer.

		°	′	″	″	″	″
33	Sugar Loaf	0	00	00·00	±0·09	−0·18	59·82
	Azimuth Mark	0	57	03·66	0·17		
34	Stabler	3	33	53·32	0·16	−0·24	53·08
35	Peach Grove	30	31	14·53	0·12	+0·84	15·37
	Leesburg	46	51	38·06	0·17		
36	Bull Run	71	25	27·26	0·18	−0·50	26·76
37	Mount Marshall	106	43	12·67	0·18	+0·08	12·75

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·93.

(*c*) *Figure adjustment.*

Observation equations of eastern part

No.	
1	$0 = -0{\cdot}37 - (1) + (3) - (10) + (11)$
2	$0 = +0{\cdot}47 - (2) + (4) - (12) + (13)$
3	$0 = -0{\cdot}75 - (3) + (4) - (9) + (10) - (12) + (14)$
4	$0 = +0{\cdot}36 - (3) + (5) - (8) + (10) - (15) + (17)$
5	$0 = -0{\cdot}29 - (6) + (8) - (17) + (18) - (26) + (27)$
6	$0 = -1{\cdot}35 - (18) + (21) - (25) + (26) - (28) + (29)$
7	$0 = -0{\cdot}922 - (20) + (21) - (28) + (32) - (33) + (34)$
8	$0 = -1{\cdot}94 - (24) + (25) - (29) + (32) - (33) + (35)$
9	$0 = +2{\cdot}09 - (30) + (32) - (33) + (36) - (39) + (40)$
10	$0 = +0{\cdot}64 - (19) + (20) - (34) + (36) - (39) + (41)$
11	$0 = +2{\cdot}50 - (23) + (24) - (35) + (36) - (39) + (42)$
12	$0 = -1{\cdot}09 - (31) + (32) - (33) + (37) - (43) + (44)$
13	$0 = -1{\cdot}40 - (36) + (37) - (38) + (39) - (43) + (45)$
14	$0 = -0{\cdot}175 - (22) + (23) + (38) - (42) - (45) + (46)$
15	$0 = -1{\cdot}0 - 2{\cdot}59\,(1) + 3{\cdot}35\,(2) + 3{\cdot}41\,(3) - 1{\cdot}83\,(4) - 0{\cdot}57\,(12) + 2{\cdot}97\,(13) - 2{\cdot}40\,(14)$
16	$0 = -14{\cdot}4 + 1{\cdot}83\,(3) - 16{\cdot}11\,(4) + 14{\cdot}28\,(5) + 30{\cdot}39\,(8) - 31{\cdot}81\,(9) + 1{\cdot}42\,(10) + 2{\cdot}11\,(15)$
	$- 8{\cdot}68\,(16) + 6{\cdot}57\,(17)$
17	$0 = -5{\cdot}1 + 0{\cdot}97\,(6) - 10\ 39\,(7) + 9{\cdot}42\,(8) - 6{\cdot}34\,(17) + 6.34\,(21) + 1{\cdot}04\,(25) - 2{\cdot}74\,(26)$
	$+ 1{\cdot}70\,(27) - 2{\cdot}06\,(28) + 2{\cdot}06\,(29)$
18	$0 = -21{\cdot}1 + 0{\cdot}74\,(18) - 44{\cdot}72\,(20) + 43{\cdot}98\,(21) + 5{\cdot}35\,(24) - 6{\cdot}39\,(25) + 1{\cdot}04\,(26) + 30{\cdot}23\,(33)$
	$- 33{\cdot}80\,(34) + 3{\cdot}57\,(35)$
19	$0 = -4{\cdot}0 + 0{\cdot}55\,(23) - 5{\cdot}35\,(24) + 4{\cdot}80\,(25) + 2{\cdot}86\,(33) - 3{\cdot}57\,(35) + 0{\cdot}71\,(36) + 3{\cdot}17\,(39)$
	$- 4{\cdot}84\,(40) + 1{\cdot}67\,(42)$
20	$0 = -0{\cdot}6 - 0{\cdot}74\,(18) + 1{\cdot}97\,(19) - 1{\cdot}23\,(21) - 0{\cdot}55\,(23) + 1{\cdot}59\,(25) - 1{\cdot}04\,(26) - 1{\cdot}42\,(40)$
	$+ 3{\cdot}09\,(41) - 1{\cdot}67\,(42)$
21	$0 = +8{\cdot}3 + 0{\cdot}98\,(23) - 1{\cdot}53\,(24) + 0{\cdot}55\,(25) + 1{\cdot}58\,(29) - 7{\cdot}31\,(30) + 5{\cdot}73\,(31) - 2{\cdot}43\,(35)$
	$+ 5{\cdot}40\,(36) - 2{\cdot}97\,(37) - 2{\cdot}42\,(43) + 5{\cdot}06\,(44) - 2{\cdot}64\,(45)$
22	$0 = +32{\cdot}7 + 26{\cdot}13\,(22) - 26{\cdot}68\,(23) + 0{\cdot}55\,(25) + 1{\cdot}58\,(29) - 7{\cdot}31\,(30) + 5{\cdot}73\,(31) + 5{\cdot}06\,(44)$
	$- 33{\cdot}46\,(45) + 28{\cdot}40\,(46)$

(*c*) *Figure adjustment*—Continued.

Correlate equations, eastern part.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
(1)	−1													
(2)		−1												
(3)	+1		−1	−1										
(4)		+1	+1											
(5)	....	....	....	+1	....	....	....	....	....	....	....	....	....	....
(6)					−1									
(7)														
(8)				−1	+1									
(9)	−1		−1											
(10)	+1	....	+1	+1	....	....	....	....	....	....	....	....	....	....
(11)														
(12)		−1	−1											
(13)		+1												
(14)			+1											
(15)	....	....	....	−1	....	....	....	....	....	....	....	....	....	....
(16)														
(17)				+1	−1									
(18)					+1	−1								
(19)										[illegible]				
(20)	....	....	....	....	....	....	[illegible]	....	....	+1	....	....	....	....
(21)						+1	+1							
(22)														
(23)											−1			−1
(24)								−1			+1			+1
(25)	....	....	....	....	....	−1	....	+1	....	....	....	....	....	....
(26)					−1	+1								
(27)					+1									
(28)						−1	−1							
(29)						+1		−1						
(30)	....	....	....	....	....	....	....	....	−1	....	....	....	....	....
(31)								+1				−1		
(32)							+1	−1	+1			+1		
(33)							−1		−1			−1		
(34)							+1			−1				
(35)	....	....	....	....	....	....	....	+1	....	....	−1	....	....	....
(36)									+1	+1	+1		−1	
(37)												+1	+1	
(38)													−1	+1
(39)									−1	−1	−1		+1	
(40)	....	....	....	....	....	....	....	....	+1	....	....	....	....	....
(41)										+1				
(42)											+1			−1
(43)												−1	−1	
(44)												+1		
(45)	....	....	....	....	....	....	....	....	....	....	....	....	+1	−1
(46)														+1

(*c*) *Figure adjustment*—Continued.

Correlate equations, eastern time—Completed.

Corrections.	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}
(1)	−2·59							
(2)	+3·35							
(3)	+3·41	+1·83						
(4)	−1·83	−16·11						
(5)	....	+14·28	....	....	....	....	....	....
(6)			+0·97					
(7)			−10·39					
(8)		+30·39	+9·42					
(9)		−31·81						
(10)	....	+1·42	....	....	....	....	....	....
(11)								
(12)	−0·57							
(13)	+2·97							
(14)	−2·40							
(15)	....	+2·11	....	....	....	....	....	....
(16)		−8·68						
(17)		+6·57	−6·34					
(18)				+0·74		−0·74		
(19)						+1·97		
(20)	....	....	....	−44·72	....	....	....	....
(21)			+6·34	+43·98		−1·23		
(22)								+26·13
(23)					+0·55	−0·55	+0·98	−26·68
(24)				+5·35	−5·35		−1·53	
(25)	....	....	+1·04	−6·39	+4·80	+1·59	+0·55	+0·55
(26)			−2·74	+1·04		−1·04		
(27)			+1·70					
(28)			−2·06					
(29)			+2·06				+1·58	+1·58
(30)	....	....	....	....	....	....	−7·31	−7·31
(31)							+5·73	+5·73
(32)								
(33)				+30·23	+2·86			
(34)				−33·80				
(35)	....	....	....	+3·57	−3·57	....	−2·43	....
(36)					+0·71		+5·40	
(37)							−2·97	
(38)								
(39)					+3·17			
(40)	....	....	....	....	−4·84	−1·42	....	....
(41)						+3·09		
(42)					+1·67	−1·67		
(43)							−2·42	
(44)							+5·06	+5·06
(45)	....	....	....	....	....	....	−2·64	−33·46
(46)								+28·40

(*c*) *Figure adjustment*—Continued.

Normal equations, eastern part.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
0 = − 0·37	+4		−2	−2										
+ 0·47		+4	+2											
− 0·75			+6	+2										
+ 0·36				+6	−2									
− 0·29	...	...	...	...	+6	−2	...	...	...	...	..	...	...	...
− 1·35						+6	+2	−2						
− 0·922							+6	+2	+2	2		+2		
− 1·94								+6	+2		−2	+2		
+ 2·09									+6	+2	+2	+2	−2	
+ 0·64	...	...	...	...	...	...	..	. .	...	+6	+2	...	−2	...
+ 2·50											+6		−2	−2
− 1·09												+6	+2	
− 1·40													+6	−2
− 0·175														+6

Normal equations, eastern part—Completed.

	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}
− 0·37	+6·00	+ 0·41						
+ 0·47	−1·64	−16·11						
− 0·75	−7·07	+15·29						
+ 0·36	−3·41	−12·06	−15·76					
− 0·29	....	+23·82	+19·23	− 0·30	....	+ 0·30	....	....
− 1·35			+ 6·68	+50·67	− 4·80	− 3·12	+ 1·03	+ 1·03
− 0·922			+ 8·40	+24·67	− 2·86	− 1·23	....	....
− 1·94			− 1·02	−38·40	+ 3·72	+ 1·59	− 1·93	− 1·03
+ 2·09				−30·23	−10·16	− 1·42	+12·71	+ 7·31
+ 0·64	....	....	...	−10·92	− 2·46	+ 1·12	+ 5·40	....
+ 2·50				+ 1·78	− 3·12	− 1·12	+ 3·52	+26·68
− 1·09				−30·23	− 2·86		− 1·22	− 0·67
− 1·40					+ 2·46		− 8·59	−33·46
− 0·175					− 1·12	+ 1·12	+ 3·62	+ 9·05
0 = − 1·0	+47·813 4	+35·721 6	....	....	....	....	....	....
−14·4		+2 527·203 4	+244·62					
− 5·1			+297·987 0	+ 269·338 0	+ 4·992 0	− 3·295 0	+ 3·826 8	+ 3·826 8
−21·1				+6 074·240 4	+ 14·418 4	−65·884 7	−20·375 1	− 3·514 5
− 4·0					+109·657 0	+11·413 4	+23·873 6	−12·034 0
− 0·6	....	....	....	....	....	+24·207 0	+ 0·335 5	+15·548 5
+ 8·3							+174·684 6	+ 176·859 5
+32·7								+3 435·402 4

Resulting values of correlates and of corrections to angular directions.

$C_1 = +0·197$	$C_9 = -0·886$	$C_{16} = -0·000\ 355$
$C_2 = -0·268$	$C_{10} = +0·004$	$O_{17} = -0·009\ 79$
$C_3 = +0·326$	$C_{11} = +0·177$	$C_{18} = +0·002\ 24$
$C_4 = -0·013$	$C_{12} = +0·240$	$C_{19} = -0·050\ 8$
$C_5 = +0·289$	$C_{13} = -0·059$	$C_{20} = +0·024\ 9$
$C_6 = +0·639$	$C_{14} = +0·051$	$C_{21} = +0·034\ 6$
$C_7 = -0·161$	$C_{15} = +0·034\ 4$	$C_{22} = -0·011\ 64$
$C_8 = +0·911$		

Resulting values of correlates and of corrections to angular directions—Completed.

″	″	″	″	″
(1)=−0·286	(11)=+0·197	(20)=+0·065	(29)=−0·256	(38)=+0·110
(2)=+0·383	(12)=−0·078	(21)=+0·484	(30)=+0·718	(39)=+0·485
(3)=+0·001	(13)=−0·166	(22)=−0·355	(31)=−0·108	(40)=−0·676
(4)=+0·001	(14)=+0·243	(23)=+0·177	(32)=+0·104	(41)=+0·082
(5)=−0·018	(15)=+0·012	(24)=−0·503	(33)=−0·182	(42)=−0·001
(6)=−0·298	(16)=+0·003	(25)=+0·056	(34)=−0·241	(43)=−0·265
(7)=+0·102	(17)=−0·242	(26)=+0·353	(35)=+0·839	(44)=+0·356
(8)=+0·199	(18)=−0·367	(27)=+0·272	(36)=−0·495	(45)=+0·188
(9)=−0·315	(19)=+0·045	(28)=−0·458	(37)=+0·078	(46)=−0·280
(10)=+0·115				

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments* (*western part*).

Mount Marshall, Rappahannock County, Virginia. July 18 to September 7, 1874. 35-centimetre theodolite, No. 10. A. T. Mosman, observer.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from first figure adjustment.	Corrections from second figure adjustment.	Final seconds in triangulations.
		°	′	″	″	″	″	″
4	Fork	0	00	00·00	±0·11		−0·20	59·80
	Maryland Heights	184	15	49·56	0·24	−0·26		49·30
	Sugar Loaf	202	41	37·50	0·16	+0·36		37·86
	Bull Run	225	17	06·78	0·17	+0·19		06·97
	Peach Grove	229	31	29·99	0·16	−0·28		29·71
	View Tree	248	47	43·70	0·19			
	National Cemetery, flag	302	03	40·42	0·31			
	Culpeper Baptist Church, spire	302	11	34·29	0·36			
3	Clark	311	50	33·98	0·17		−0·25	33·73
	Peters	336	20	36·44	0·16			
					Mean	0·00		

Probable error of a single observation of a direction (D. and R.) = ± 1″·29.

Bull Run, Fauquier County, Virginia. September 22 to November 28, 1871. 75-centimetre theodolite, No. 1. C. O. Boutelle, observer.

	Objects observed.	°	′	″	″	″	″	″
	Azimuth Mark	0	00	00·00	±0·12			
1	Clark	1	07	09·35	0·19		−0·24	09·11
	View Tree	13	44	29·24	0·08			
2	Fork	33	03	17·51	0·18		+0·52	18·03
	Mount Marshall	53	39	05·53	0·22	+0·11		05·64
	Paris	92	24	57·37	0·27			
	Maryland Heights	157	20	07·15	0·24	+0·49		07·64
	Leesburg	179	01	37·56	0·30			
	Sugar Loaf	190	54	06·98	0·21	−0·68		06·30
	Stabler	225	12	03·95	0·15	+0·08		04·03
	Peach Grove	242	29	57·85	0·18	0·00		57·85
					Mean	0·00		

Probable error of a single observation of a direction (D. and R.) = ± 1″·09.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments* (*western part*)—Continued.

Clark, Orange County, Virginia. July 24 to September 5, 1871. 75-centimetre theodolite, No. 1. C. O. Boutelle, observer.

Number of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
5	Spear	0	00	00·00	±0·17	−0·12	59·88
	Peters	11	21	47·00	0·15		
6	Humpback	24	09	37·37	0·16	−1·35	36·02
	Azimuth Mark	55	29	20·96	0·12		
7	Fork	78	26	10·17	0·17	+0·97	11·14
8	Mount Marshall	122	25	05·12	0·17	+0·02	05·14
	View Tree	158	12	53·81	0·20		
9	Bull Run	163	19	47·57	0·18	+0·48	48·05
	Hundley	223	43	11·53	0·18		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·03.

Fork, Madison County, Virginia. October 12 to December 24, 1874. 35-centimetre theodolite, No. 10. A. T. Mosman, observer. July 18 to August 6, 1879. 50-centimetre theodolite, No. 114. A. T. Mosman, observer.

Number of direction.	Objects observed.	°	′	″	″	″	″
	Peaked	0	00	00·00	±0·08		
16	Slate Springs	20	16	00·96	0·15	+0·98	01·94
10	Mount Marshall	136	25	13·62	0·17	+0·39	14·01
11	Bull Run	161	06	37·64	0·16	−1·01	36·63
12	Clark	224	16	58·68	0·19	−0·86	57·82
	Peters	270	56	24·51	0·20		
13	Spear	303	52	39·51	0·19	−0·10	39·41
	Jarman	321	52	29·41	0·20		
14	Humpback	322	58	40·96	0·15	−0·20	40·76
15	Elliott Knob	353	33	11·50	0·13	+0·80	12·30

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·24.

Spear, Buckingham County, Virginia. July 30 to August 29, 1875. 35-centimetre theodolite, No. 10. A. T. Mosman, observer.

Number of direction.	Objects observed.	°	′	″	″	″	″
	Willis	0	00	00·00	±0·13		
	Long	113	14	26·50	0·21		
	Smith	119	19	24·25	0·19		
	Flat Top	150	15	15·49	0·20		
17	Tobacco Row	160	17	43·42	0·16	+0·22	43·64
18	Humpback	233	59	02·50	0·21	−0·44	02·06
	Jarman	251	08	16·40	0·28		
19	Fork	266	07	14·11	0·22	+0·05	14·16
	Peters	283	15	22·59	0·29		
20	Clark	288	05	31·91	0·22	+0·17	32·08

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·37.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments* (*western part*)—Continued.

Tobacco Row, Amherst County, Virginia. September 14 to September 23, 1875. 35-centimetre theodolite, No. 10. A. T. Mosman, observer. September 6 to September 9, 1879. 50-centimetre theodolite, No. 114. A. T. Mosman, observer.

Number of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
	Flat Top	0 00 00·00	±0·15		
21	Bald Knob	54 31 49·35	0·14	−0·65	48·70
22	Humpback	140 52 23·38	0·16	+0·86	24·24
23	Spear	200 19 28·80	0·16	−0·21	28·59
	Willis	208 43 28·06	0·26		
	Long Mountain	272 56 37·39	0·18		
	Lynchburg	276 15 52·23	0·35		
	Smith	318 30 40·14	0·24		
	Cahas	345 52 24·62	0·32		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·43.

Humpback. Nelson County, Virginia. June 8 to June 29, 1875. 35-centimetre theodolite, No. 10. A. T. Mosman, observer. May 11 to June 6, 1878. 50-centimetre theodolite, No. 114. A. T. Mosman, observer. August 18 to August 28, 1879. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers.

Number of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
	Jarman	0 00 00·00	±0·11		
25	Clark	24 30 20·46	0·17	+1·37	21·83
	Peters	31 40 01·24	0·34		
26	Spear	126 14 25·02	0·24	+0·44	25·46
	Long Mountain	154 41 57·10	0·19		
27	Tobacco Row	173 06 07·68	0·10	−0·87	06·81
28	Bald Knob	230 26 24·65	0·14	+0·17	24·82
29	Paddy	256 16 18·23	0·12	+0·15	18·38
30	Elliott Knob	265 35 01·13	0·16	−1·03	00·10
31	Slate Springs	300 08 53·99	0·13	−0·57	53·42
	Peaked	334 47 31·47	0·21		
24	Fork	357 28 32·18	0·14	+0·33	32·51
	Jarman 2	359 59 03·47	0·07		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·28.

Bald Knob. Bath County, Virginia. September 1 to September 19, 1878. 50-centimetre theodolite, No. 114. A. T. Mosman, observer. September 25 to September 27, 1879. 50-centimetre theodolite, No. 114. A. T. Mosman, observer.

Number of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
50	Paddy	0 00 00·00	±0·08	+0·08	00·08
	Flag Rock	20 41 52·01	0·12		
51	Elliott Knob	53 00 16·88	0·11	−0·02	16·86
52	Humpback	80 40 00·22	0·09	+0·06	00·28
53	Tobacco Row	116 59 14·97	0·12	+0·66	15·63
48	Keeney	250 18 60·00	0·12	−0·34	59·66
49	Briery	292 07 57·15	0·14	−0·44	56·71

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·78.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments* (*western part*)—Continued.

Elliott Knob. Augusta County, Virginia. July 3 to August 6, 1878. 50-centimetre theodolite, No. 114. A. T. Mosman, observer.

Number of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
38	Humpback	0	00	00 ·00	±0 ·08	+0 ·47	00 ·47
39	Bald Knob	117	11	47 ·35	0 ·11	−0 ·22	47 ·13
40	Briery	145	20	10 ·67	0 ·10	+0 ·62	11 ·29
41	Paddy	161	21	32 ·80	0 ·12	+0 ·35	33 ·15
	Collimator	238	16	10 ·94	0 ·12		
36	Slate Springs	253	07	38 ·17	0 ·16	−0 ·11	38 ·06
	Peaked	298	35	36 ·95	0 ·18		
37	Fork	302	27	57 ·49	0 ·10	−1 ·11	56 ·38
	Jarman 2	334	09	02 ·50	0 ·18		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·79.

Slate Springs. Rockingham County, Virginia. October 12 to November 1, 1878. 30-centimetre theodolite, No. 118. W. B. Fairfield, observer.

Number of direction.	Objects observed.	°	′	″	Approximate probable error. ″	Corrections from figure adjustment. ″	Final seconds in triangulation. ″
34	Elliott Knob	0	00	00 ·00	±0 ·13	−0 ·04	59 ·96
35	Paddy	46	40	33 ·81	0 ·15	+0 ·20	34 ·01
32	Fork	256	03	02 ·20	0 ·14	−0 ·85	01 ·35
	Peaked	273	01	23 ·99	0 ·22		
33	Humpback	321	26	10 ·80	0 ·11	+0 ·68	11 ·48

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·87.

Paddy. Highland County, Virginia. October 12 to October 20, 1878. 50-centimetre theodolite, No. 114. A. T. Mosman, observer.

Number of direction.	Objects observed.	°	′	″	Approximate probable error. ″	Corrections from figure adjustment. ″	Final seconds in triangulation. ″
45	Bald Knob	0	00	00 ·00	±0 ·09	+0 ·02	00 ·02
46	Keeney	48	34	42 ·87	0 ·16	+0 ·23	43 ·10
47	Briery	67	10	39 ·42	0 ·12	+0 ·10	39 ·52
42	Slate Springs	235	36	33 ·14	0 ·14	+0 ·04	33 ·18
43	Elliott Knob	277	09	59 ·68	0 ·13	−1 ·06	58 ·62
44	Humpback	286	29	45 ·11	0 ·14	+0 ·67	45 ·78
	Flag Rock	347	58	28 ·25	0 ·25		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·81.

Briery, Pocahontas County, West Virginia. July 7 to July 23, 1880. 50-centimetre theodolite, No. 114. A. T. Mosman, observer.

Number of direction.	Objects observed.	°	′	″	Approximate probable error. ″	Corrections from figure adjustment. ″	Final seconds in triangulation. ″
58	Beech	0	00	00 ·00	±0 ·11	−0 ·59	59 ·41
59	Summersville	27	18	53 ·06	0 ·16	+0 ·62	53 ·68
54	Paddy	172	53	40 ·28	0 ·11	−0 ·35	39 ·93
55	Elliott Knob	186	51	40 ·16	0 ·11	−0 ·21	39 ·95
56	Bald Knob	217	51	01 ·11	0 ·16	+0 ·39	01 ·50
57	Keeney	316	27	40 ·03	0 ·11	+0 ·14	40 ·17
	Job	346	18	55 ·46	0 ·25		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·83.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments* (*western part*)—Completed.

Keeney, Summers County, West Virginia. August 28 to September 16, 1880. 50-centimetre theodolite, No. 114. A. T. Mosman, observer.

Number of direction.	Objects observed.	Resulting directions from station adjustment.			Appropriate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
	Azimuth Mark	0	00	00·00	±0·07		
65	Beech	11	26	15·15	0·07	+0·29	15·44
66	Briery	35	48	16·10	0·08	−0·12	15·98
67	Paddy	53	38	23·32	0·10	−0·11	23·21
68	Bald Knob	75	22	46·36	0·07	+0·36	46·72
64	Ivy	269	50	30·28	0·10	−0·41	29·87

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·53.

Beech, Greenbrier County, West Virginia. October 8 to October 22, 1880. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers.

Number of direction.	Objects observed.	°	′	″	″	″	″
60	Briery	0	00	00·00	±0·12	+0·52	00·52
	Job	42	17	23·09	0·22		
61	Keeney	112	05	43·17	0·14	−0·33	42·84
62	Ivy	164	20	17·69	0·19	−0·08	17·61
63	Summersville	228	11	10·08	0·16	−0·11	09·97

Probable error of a single observation of a direction (*D.* and *R.*) = ±1″·08.

Summersville, Nicholas County, West Virginia. November 9 to December 5, 1880. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
72	Beech	0	00	00·00	±0·11		+0·05	00·05
	Ivy	95	56	58·36	0·30	−0·27		58·09
	Table Rock	132	04	23·34	0·13	+0·29		23·63
	Holmes	155	27	36·85	0·21	−0·02		36·83
71	Briery	339	07	44·10	0·12		−0·54	43·56
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·86.

Ivy, Raleigh County, West Virginia. June 14 to June 21, 1881. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
	Table Rock	0	00	00·00	±0·14	−0·05		59·95
	Holmes	6	33	23·49	0·15	+0·15		23·64
	Summersville	58	22	03·66	0·14	−0·09		03·57
69	Beech	78	34	19·05	0·14		−0·05	19·00
70	Keeney	104	44	04·82	0·19		+0·49	05·31
	Pigeon	327	57	11·54	0·13	+0·09		11·63
	Piney	339	33	29·00	0·17	−0·10		28·90
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·81.

(*c*) *Figure adjustment.*

Observation equations of western part.

1 $0 = -0.45 - (1) + (3) - (8) + (9)$

2 $0 = +2.11 - (2) + (4) - (10) + (11)$

3 $0 = +2.14 - (3) + (4) - (7) + (8) - (10) + (12)$

4 $0 = -0.50 - (13) + (14) - (18) + (19) - (24) + (26)$

5 $0 = +1.55 - (5) + (6) - (18) + (20) - (25) + (26)$

6 $0 = -1.97 - (5) + (7) - (12) + (13) - (19) + (20)$

7 $0 = 0.00 - (15) + (16) - (32) + (34) - (36) + (37)$

8 $0 = -3.94 - (14) + (15) + (24) - (30) - (37) + (38)$

9 $0 = -0.33 - (30) + (31) - (33) + (34) - (36) + (38)$

10 $0 = +3.05 - (17) + (18) - (22) + (23) - (26) + (27)$

11 $0 = +1.82 - (28) + (30) - (38) + (39) - (51) + (52)$

12 $0 = -3.15 - (21) + (22) - (27) + (28) - (52) + (53)$

13 $0 = +1.32 - (34) + (35) + (36) - (41) - (42) + (43)$

14 $0 = -0.42 - (29) + (30) \quad (38) + (41) - (43) + (44)$

15 $0 = +0.70 - (28) + (29) - (44) + (45) - (50) + (52)$

16 $0 = -1.34 - (45) + (47) - (49) + (50) - (54) + (56)$

17 $0 = -1.86 - (39) + (40) - (49) + (51) - (55) + (56)$

18 $0 = -0.14 - (48) - (49) - (56) + (57) - (66) + (68)$

19 $0 = -1.10 - (45) + (46) - (48) + (50) - (67) + (68)$

20 $0 = +1.99 - (57) + (58) - (60) + (61) - (65) + (66)$

21 $0 = -1.49 - (61) + (62) - (64) + (65) - (69) + (70)$

22 $0 = -2.42 - (58) + (59) + (60) - (63) - (71) + (72)$

23 $0 = +0.13 - (62) + (63) + (69) - (72)$

24 $0 = -6.2 + 1.61(1) - 5.60(2) + 2.18(7) - 4.61(8) + 2.43(9) + 4.50(10) - 4.58(11) + 0.08(12)$

25 $0 = -8.2 + 4.69(5) - 6.20(6) + 1.51(7) - 0.32(12) - 6.08(13) + 6.40(14) + 1.82(18)$
$\quad - 3.35(19) + 1.53(20)$

26 $0 = -0.4 + 1.35(14) - 4.18(15) + 2.83(16) + 1.35(24) - 3.06(30) - 4.41(31) + 2.43(36)$
$\quad - 1.80(37) - 0.63(38)$

27 $0 = -4.7 + 6.08(13) - 9.65(14) + 3.57(15) + 0.62(17) - 3.97(18) + 3.35(19) + 0.14(21)$
$\quad - 1.38(22) + 1.24(23) + 1.33(37) - 0.24(38) - 1.09(39) + 4.01(51) - 6.88(52) + 2.87(53)$

28 $0 = -43.7 + 12.84(29) - 15.90(30) + 3.06(31) + 2.64(33) - 4.63(34) + 1.99(35) + 2.37(42)$
$\quad - 15.19(43) + 12.82(44)$

29 $0 = -10.8 + 3.00(28) - 6.06(30) + 3.06(31) + 2.64(33) - 4.63(34) + 1.99(35) + 2.37(42)$
$\quad - 2.64(43) + 0.27(45) + 1.58(50) - 5.59(51) + 4.01(52)$

30 $0 = +3.5 + 2.17(39) - 7.33(40) + 5.16(41) + 0.85(49) - 2.43(50) + 1.58(51) + 6.36(54)$
$\quad - 8.46(55) + 2.10(56)$

31 $0 = -1.0 + 0.88(45) - 6.26(46) + 5.38(47) + 2.36(48) - 3.21(49) + 0.85(50) + 4.00(66)$
$\quad - 6.55(67) + 2.55(68)$

32 $9 = -4.3 + 2.21(57) - 6.29(58) + 4.08(59) - 0.43(64) - 4.22(65) + 4.65(66) - 10.01(69)$
$\quad + 4.29(70) + 5.52(71) - 5.30(72)$

33 $0 = +10.8 - 1.61(1) - 1.89(3) + 1.89(4) - 1.51(6) + 1.51(7) + 2.43(8) - 2.43(9) + 0.08(10)$
$\quad - 0.08(12) - 3.57(14) + 3.57(15) + 4.13(24) - 4.13(25) - 3.00(28) + 3.00(30) + 1.33(37)$
$\quad - 1.33(38) - 2.17(39) + 2.17(41) + 0.27(43) - 1.15(45) + 0.88(47) - 2.36(48) + 2.36(49)$
$\quad + 4.01(51) - 4.01(52) + 2.10(54) - 2.10(56) - 2.21(57) + 2.21(58) - 0.85(60) + 0.85(61)$
$\quad - 1.03(62) + 1.03(63) + 0.43(64) - 0.43(65) + 2.55(66) - 2.55(68) - 0.22(72) + 4.29(69)$
$\quad - 4.29(70)$

(*c*) *Figure adjustment*—Continued.

Correlate equations, western part.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
(1)	−1																			
(2)		−1																		
(3)	+1		−1																	
(4)		+1	+1																	
(5)	....	....	....	....	−1	−1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
(6)					+1															
(7)			−1			+1														
(8)	−1		+1																	
(9)	+1																			
(10)	....	−1	−1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
(11)		+1																		
(12)			+1			−1														
(13)				−1		+1														
(14)				+1				−1												
(15)	....	....	....	....	...	....	−1	+1	....	....	....	....	....	....	....	....	....	....	....	....
(16)							+1													
(17)										−1										
(18)				−1	−1					+1										
(19)				+1		−1														
(20)	....	....	....	....	+1	+1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
(21)												−1								
(22)										−1		+1								
(23)										+1										
(24)				−1				+1												
(25)	....	....	....	....	−1	....	....	....	....	....	....	...	....	....	....	....	....	....	....	....
(26)				+1	+1					−1										
(27)										+1		−1								
(28)											−1	+1			−1					
(29)														−1	+1					
(30)	....	....	....	....	....	....	....	−1	−1	....	+1	....	....	+1	....	....	....	....	....	....
(31)									+1											
(32)							−1													
(33)									−1											
(34)							+1		+1				−1							
(35)	....	....	....	....	....	....	....	....	....	....	....	....	+1	....	....	....	....	....	....	....
(36)							−1		−1				+1							
(37)							+1	−1												
(38)								+1	+1		−1			−1						
(39)											+1						−1			
(40)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+1	....	....	....
(41)													−1	+1						
(42)													−1							
(43)													+1	−1						
(44)														+1	−1					
(45)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+1	−1	....	....	−1	....
(46)																			+1	
(47)																+1				
(48)																		−1	−1	
(49)																−1	−1	+1		
(50)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	−1	+1	....	....	+1	....
(51)											−1						+1			
(52)											+1	−1			+1					
(53)												+1								
(54)																−1				
(55)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	−1	....	....	....
(56)																+1	+1	−1		
(57)																		+1		−1

(*c*) *Figure adjustment*—Continued.

Correlate equations, western part—Continued.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
(58)																				+1
(59)																				
(60)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	−1
(61)																				+1
(62)																				
(63)																				
(64)																				
(65)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	−1
(66)																		−1		+1
(67)																			−1	
(68)																		1	+1	

Correlate equations, western part—Completed.

Corrections.	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}
(1)				+1·61									−1·61
(2)				−5·60									
(3)													−1·89
(4)													+1·89
(5)	....	....	...	....	+4·69	....	....	....	....	....	....	....	....
(6)					−6·20								−1·51
(7)				+2·18	+1·51								+1·51
(8)				−4·61									+2·43
(9)				+2·43									−2·43
(10)	....	....	....	+4·50	....	....	....	....	....	....	....	....	+0·08
(11)				−4·58									
(12)				+0·08	−0·32								−0·08
(13)					−6·08		+6·08						
(14)					+6·40	+1·35	−9·65						−3·57
(15)	....	....	....	....	....	−4·18	+3·57	....	....	....	....	....	+3·57
(16)						+2·83							
(17)							+0·62						
(18)					+1·82		−3·97						
(19)					−3·25		+3·35						
(20)	....	....	.. .	....	+1·53	....	....	....	....	....	....	....	....
(21)							+0·14						
(22)							−1·38						
(23)							+1·24						
(24)						+1·35							+4·13
(25)	....	....	....	....	....	....	....	....	....	....	....	....	−4·13
(26)													
(27)													
(28)									+3·00				−3·00
(29)								+12·84					
(30)	....	....	....	....	....	+3·06	....	−15·90	−6·06	....	....	....	+3·00
(31)						−4·41		+ 3·06	+3·06				
(32)													
(33)								+ 2·64	+2·64				
(34)								− 4·63	−4·63				
(35)	....	....	....	....	....	....	....	+ 1·99	+1·99	....	....	....	....
(36)						+2·43							
(37)						−1·80	+1·33						+1·33
(38)						−0·63	−0·24						−1·33
(39)							−1·09			+2·17			−2·17
(40)	....	....	....	....	....	....	....	....	....	−7·33	....	....	....
(41)										+5·16			+2·17

(*c*) *Figure adjustment*—Continued.

Correlate equations, western part—Completed.

Corrections.	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}
(42)								+ 2·37	+2·37				
(43)								−15·19	−2·64				+0·27
(44)								+12·82					
(45)	....	....	....	....	....	....	....	....	+0·27	....	+0·88	....	−1·15
(46)											−6·26		
(47)											+5·38		+0·68
(48)											+2·36		−2·36
(49)										+0·85	−3·21		+2·36
(50)	....	....	....	....	....	....	....	....	+1·58	−2·43	+0·85	....	....
(51)							+4·01		−5·59	+1·58			+4·01
(52)							−6·88		+4·01				−4·01
(53)							+2·87						
(54)										+6·36			+2·10
(55)	....	....	....	....	....	....	....	....	....	−8·46	....	....	....
(56)										+2·10			−2·10
(57)												+ 2·21	−2·21
(58)		−1										− 6·29	+2·21
(59)		+1										+ 4·08	
(60)	....	+1	....	....	....	....	....	....	....	....	....	....	−0·85
(61)	−1												+0·85
(62)	+1		−1										−1·03
(63)		−1	+1										+1·03
(64)	−1											− 0·43	+0·43
(65)	+1	....	....	....	....	....	....	....	....	....	....	− 4·22	−0·43
(66)											+4·00	+ 4·65	+2·55
(67)											−6·55		
(68)											+2·55		− 2·55
(69)	−1		+1									−10·01	+4·29
(70)	+1	....	....	....	....	...	....	....	....	....	....	+ 4·29	−4·29
(71)		−1										+ 5·52	
(72)		+1	−1									− 5·30	−0·22

Normal equations, western part.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
0 = − 0·45	+4		−2																	
+ 2·11	.	+4	+2																	
+ 2·14			+6			−2														
− 0·50				+6	+2	−2		−2		−2										
+ 1·55	...	...	...	...	+6	+2	...	...	...	−2	...	...	...	...	...	...	...	...	...	...
− 1·97						+6														
0·00							+6	−2	+2				−2							
− 3·94								+6	+2		−2			−2						
− 0·33									+6		−2		−2	−2						
+ 3·05	...	...	...	...	...	...	..	...	...	+6	...	−2	...	...	...	...	. .	..	...	..
+ 1·82											+6	−2		+2	+2		−2			
− 3·15												+6			−2					
+ 1·32													+6	−2						
− 0·42														+6	−2					
+ 0·70	...	...	...	...	...	...	...	...	...	...	...	...	...	..	+6	−2	...	...	−2	. .
− 1·34																+6	+2	−2	+2	
− 1·86																	+6	−2		
− 0·14																		+6	+2	−2
− 1·10																			+6	
+ 1·99	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+6

(*c*) *Figure adjustment*—Continued.

Normal equations, western part—Completed.

	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}
− 0·45				+ 5·43									− 5·14
+ 2·11				− 3·48									+ 1·81
+ 2·14				−11·21	− 1·83								+ 4·54
- 0·50					+ 7·31		-· 8·41						− 7·70
+ 1·55	...	...	...	....	−11·18	....	+ 3·97	....	....	....	....	....	+ 2·62
− 1·97				+ 2·10	− 4·06		+ 2·73						+ 1·59
0·00						+ 2·78	− 2·24	− 4·63	− 4·63				− 2·24
− 3·94					− 6·40	− 6·07	+11·65	+15·90	+ 6·06				+ 5·61
− 0·33						−10·53	− 0·24	+11·69	+ 1·85				− 4·33
+ 3·05	...	...	...	....	+ 1·82	....	− 1·97	....	....	....	....	....	....
+ 1·82						+ 3·69	−11·74	−15·90	+ 0·54	+ 0·59			− 2·86
− 3·15							+ 8·23		− 1·01				+ 1·01
+ 1·32						+ 2·43		−10·94	+ 1·61	− 5·16			− 1·90
− 0·42						+ 3·69	+ 0·24	− 0·73	− 3·42	+ 5·16			+ 6·23
+ 0·70	...	...	...	....	....	...	− 6·88	+ 0·02	− 0·30	+ 2·43	+ 0·03	....	− 2·16
− 1·34									+ 1·31	− 7·54	+ 8·56		− 4·53
− 1·86							+ 5·10		− 5·59	+ 1·79	+ 3·21		+ 1·72
− 0·14										− 1·25	− 7·02	− 2·44	− 0·49
− 1·10									+ 1·31	− 2·43	+ 0·45		+ 0·96
+ 1·99	−2	−2	...	....	....	....	....	....	....	....	+ 4·00	+ 0·37	+ 9·10
0=− 1·49	+6		−2									+10·51	−11·32
− 2·42		+6	−2									− 0·45	− 4·31
+ 0·13			+4									− 4·71	+ 6·57
− 6·2				+107·094	+3·2662								−16·054
− 8·2	...	...	...	....	+157·621	+ 8·640	−117·174	....	....	....	....	....	−11·180
− 0·4						+67·480	− 30·193	−62·149	−32·038				− 6·543
− 4·7							+248·329		−·50·005	+ 3·970			+95·318
−43·7								+860·111	+183·803				−51·801
-10·8									+149·938	−12·672	+ 1·581		−66·699
+ 3·5	...	...	...	....	....	....	....	....	....	+210·618	− 4·794	....	+23·776
− 1·0											+150·908	+18·600	− 5·725
− 4·3												+277·875	−65·479
+ 10·8													+234·534

Resulting values of correlates.

C_1=+0·338	C_{10}=−0·219	C_{18}=+0·177	C_{26}=+0·045 2
C_2=−0·786	C_{11}=+0·245	C_{19}=+0·171	C_{27}=+0·003 31
C_3=+0·613	C_{12}=+0·648	C_{20}=+0·080	C_{28}=+0·031 8
C_4=+1·544	C_{13}=+0·091	C_{21}=+0·400	C_{29}=+0·023 8
C_5=−1·320	C_{14}=+0·599	C_{22}=+0·585	C_{30}=−0·026 1
C_6=+1·478	C_{15}=+0·339	C_{23}=+0·490	C_{31}=−0·008 66
C_7=+0·850	C_{16}=+0·159	C_{24}=+0·048 3	C_{32}=−0·008 75
C_8=+1·867	C_{17}=+0·433	C_{25}=+0·008 5	C_{33}=−0·012 3
C_9=−0·538			

Resulting corrections to angular directions.

″	″	″	″
(1)=−0.240	(19)=+0.048	(37)=−1.110	(55)=−0.212
(2)=+0.516	(20)=+0.171	(38)=+0.472	(56)=+0.386
(3)=−0.252	(21)=−0.647	(39)=−0.222	(57)=+0.144
(4)=−0.196	(22)=+0.862	(40)=+0.624	(58)=−0.587
(5)=−0.118	(23)=−0.215	(41)=+0.347	(59)=+0.620
(6)=−1.354	(24)=+0.333	(42)=+0.041	(60)=+0.515
(7)=+0.965	(25)=+1.371	(43)=−1.057	(61)=−0.330
(8)=+0.022	(26)=+0.443	(44)=+0.668	(62)=−0.077
(9)=+0.485	(27)=−0.867	(45)=+0.022	(63)=−0.108
(10)=+0.389	(28)=+0.172	(46)=+0.225	(64)=−0.409
(11)=−1.007	(29)=+0.148	(47)=+0.102	(65)=+0.288
(12)=−0.863	(30)=−1.033	(48)=−0.339	(66)=−0.122
(13)=−0.098	(31)=−0.567	(49)=−0.438	(67)=−0.114
(14)=−0.195	(32)=−0.850	(50)=+0.085	(68)=+0.357
(15)=+0.796	(33)=+0.685	(51)=−0.022	(69)=+0.050
(16)=+0.978	(34)=−0.036	(52)=+0.058	(70)=+0.490
(17)=+0.221	(35)=+0.202	(53)=+0.657	(71)=−0.537
(18)=−0.440	(36)=−0.111	(54)=−0.351	(72)=+0.051

(*d*) *Adjusted triangles, Maryland, Virginia, and West Virginia.*

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
1	Hill	56	40	32.00	+0.08	32.08	0.46	4.392 324 7	24 678.84
	Webb	53	10	52.09	0.00	52.09	0.46	4.373 719 9	23 643.94
	Marriott	70	08	36.93	+0.29	37.22	0.47	4.443 721 1	27 779.29
				1.02			1.39		
2	Soper	39	41	37.08	−0.09	36.99	0.49	4.392 324 7	24 678.84
	Webb	102	15	58.28	0.00	58.28	0.48	4.577 012 1	37 758.27
	Marriott	38	02	26.57	−0.38	26.19	0.49	4.376 775 6	23 810.89
				1.93			1.46		
3	Soper	75	01	10.92	+0.32	11.24	0.43	4.443 721 1	27 779.29
	Webb	49	05	06.19	0.00	06.19	0.42	4.337 076 1	21 730.82
	Hill	55	53	43.41	+0.43	43.84	0.42	4.376 775 8	23 810.90
				0.52			1.27		
4	Soper	35	19	33.84	+0.41	34.25	0.40	4.373 719 9	23 643.94
	Marriott	32	06	10.36	+0.67	11.03	0.40	4.337 076 2	21 730.82
	Hill	112	34	15.41	+0.51	15.92	0.40	4.577 012 2	37 758.28
				59.61			1.20		
5	Stabler	44	54	03.49	−0.01	03.48	0.08	4.376 775 7	23 810.90
	Webb	8	23	06.84	−0.02	06.82	0.08	3.691 882 4	4 919.06
	Soper	126	42	....	....	49.94	0.08	4.432 017 4	27 040.67
							0.24		

(*d*) *Adjusted triangles, Maryland, Virginia, and West Virginia*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
6	Stabler	62	40	22·32	−0·26	22·06	0·53	4·443 721 1	27 779·29
	Webb	57	28	13·03	−0·02	13·01	0·54	4·420 998 3	26 363·21
	Hill	59	51	26·62	−0·08	26·54	0·54	4·432 017 4	27 040·67
				01·97			1·61		
7	Stabler	17	46	18·83	−0·245	18·585	0·034	4·337 076 1	21 730·82
	Soper	158	15	....	....	58·820	0·033	4·420 998 3	26 363·21
	Hill	3	57	43·21	−0·514	42·696	0·034	3·691 882 5	4 919·06
							0·101		
8	Peach Grove	51	03	01·00	−0·08	00·92	0·62	4·420 998 3	26 363·21
	Stabler	63	40	03·06	−0·13	02·93	0·62	4·482 609 8	30 381·54
	Hill	65	16	57·50	+0·50	58·00	0·61	4·488 456 8	30 793·34
				01·56			1·85		
9	Sugar Loaf	18	22	....	....	03·65	0·62	4·420 998 3	26 363·21
	Stabler	134	09	42·34	+0·73	43·07	0·61	4·778 281 4	60 017·99
	Hill	27	28	15·03	+0·10	15·13	0·62	4·586 513 6	38 593·45
							1·85		
10	Sugar Loaf	45	42	51·12	+0·20	51·32	0·95	4·488 456 8	30 793·34
	Stabler	70	29	39·28	+0·85	40·13	0·94	4·607 957 7	40 546·91
	Peach Grove	63	47	31·09	+0·30	31·39	0·95	4·586 513 6	38 593·45
				01·49			2·84		
11	Sugar Loaf	27	20	....	....	47·66	0·95	4·482 609 8	30 381·54
	Hill	37	48	42·47	+0·40	42·87	0·95	4·607 957 8	40 546·92
	Peach Grove	114	50	32·09	+0·22	32·31	0·94	4·778 281 4	60 017·99
							2·84		
12	Maryland Heights	3	33	53·32	−0·059	53·261	0·104	4·586 513 6	38 593·45
	Sugar Loaf	173	44	18·32	+0·562	18·882	0·104	4·830 573 0	67 697·56
	Stabler	2	41	47·75	+0·419	48·169	0·104	4·465 432 7	29 203·35
				59·39			0·312		
13	Maryland Heights	30	31	14·53	+1·02	15·55	0·79	4·607 957 7	40 546·91
	Sugar Loaf	128	01	27·20	+0·36	27·56	0·79	4·798 611 0	62 894·26
	Peach Grove	21	27	18·70	+0·56	19·26	0·79	4·465 432 7	29 203·35
				00·43			2·37		
14	Maryland Heights	26	57	21·21	+1·08	22·29	1·63	4·488 456 8	30 793·34
	Stabler	67	47	51·53	+0·43	51·96	1·63	4·798 611 1	62 894·28
	Peach Grove	85	14	49·79	+0·86	50·65	1·64	4·830 573 0	67 697·56
				02·53			4·90		

(*d*) *Adjusted triangles, Maryland, Virginia, and West Virginia*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
15	Bull Run	33	33	59·83	−1·16	58·67	1·20	4·465 432 7	29 203·35
	Maryland Heights	71	25	27·26	−0·31	26·95	1·20	4·699 551 7	50 067·01
	Sugar Loaf	75	00	38·59	−0·62	37·97	1·19	4·707 753 2	51 021·49
				05·68			3·59		
16	Bull Run	67	51	56·80	−0·40	56·40	2·70	4·830 573 0	67 697·56
	Maryland Heights	67	51	33·94	−0·26	33·68	2·71	4·830 553 5	67 694·52
	Stabler	44	16	38·02	+0·02	38·04	2·71	4·707 753 2	51 021·49
				08·76			8·12		
17	Bull Run	85	09	50·70	−0·49	50·21	1·77	4·798 611 0	62 894·26
	Maryland Heights	40	54	12·73	−1·33	11·40	1·78	4·616 253 0	41 328·82
	Peach Grove	53	56	04·40	−0·68	03·72	1·78	4·707 753 3	51 021·51
				07·83			5·33		
18	Bull Run	34	17	56·97	+0·76	57·73	1·62	4·586 513 6	38 593·45
	Sugar Loaf	98	43	39·73	+1·18	40·91	1·61	4·830 553 5	67 694·52
	Stabler	46	58	25·77	+0·44	26·21	1·62	4·699 551 6	50 067·00
				02·47			4·85		
19	Bull Run	51	35	50·87	+0·68	51·55	1·37	4·607 957 7	40 546·91
	Sugar Loaf	53	00	48·61	+0·98	49·59	1·37	4·616 253 0	41 328·82
	Peach Grove	75	23	23·10	−0·12	22·98	1·38	4·699 551 7	50 067·01
				02·58			4·12		
20	Bull Run	17	17	53·90	−0·08	53·82	0·70	4·488 456 8	30 793·34
	Stabler	23	31	13·51	+0·41	13·92	0·70	4·616 253 1	41 328·83
	Peach Grove	139	10	54·19	+0·18	54·37	0·71	4·830 553 6	67 694·53
				01·60			2·11		
21	Mount Marshall	18	25	47·94	+0·62	48·56	1·79	4·465 432 7	29 203·35
	Maryland Heights	106	43	12·67	+0·26	12·93	1·78	4·946 793 1	88 469·41
	Sugar Loaf	54	51	03·66	+0·21	03·87	1·79	4·878 122 3	75 530·49
				04·27			5·36		
22	Mount Marshall	41	01	17·22	+0·45	17·67	1·88	4·707 753 2	51 021·49
	Maryland Heights	35	17	45·41	+0·57	45·98	1·88	4·652 400 4	44 915·93
	Bull Run	103	41	01·62	+0·38	02·00	1·89	4·878 122 2	75 530·47
				04·25			5·65		
23	Mount Marshall	45	15	40·43	−0·01	40·42	3·90	4·798 611 0	62 894·26
	Maryland Heights	76	11	58·14	0·76	57·38	3·91	4·934 439 0	85 988·24
	Peach Grove	58	32	34·06	−0·15	33·91	3·90	4·878 122 3	75 530·49
				12·63			11·71		

(*d*) *Adjusted triangles, Maryland, Virginia, and West Virginia*—Continued.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
24	Mount Marshall	22	35	29.28	−0.17	29.11	1.29	4.699 551 7	50 067.01
	Sugar Loaf	20	09	34.93	−0.83	34.10	1.29	4.652 400 5	44 915.94
	Bull Run	137	14	61.45	−0.78	60.67	1.30	4.946 793 1	88 469.41
				05.66			3.88		
25	Mount Marshall	26	49	52.49	−0.63	51.86	2.91	4.607 957 7	40 546.91
	Sugar Loaf	73	10	23.54	+0.15	23.69	2.91	4.934 439 1	85 988.25
	Peach Grove	79	59	52.76	+0.41	53.17	2.90	4.946 793 1	88 469.41
				08.79			8.72		
26	Mount Marshall	4	14	23.21	−0.468	22.742	0.242	4.616 253 0	41 328.82
	Bull Run	171	09	07.68	+0.111	07.791	0.241	4.934 439 0	85 988.24
	Peach Grove	4	36	29.66	+0.532	30.192	0.242	4.652 400 4	44 915.93
				00.55			0.725		
27	Clark	40	54	42.45	+0.46	42.91	2.07	4.652 400 4	44 915.93
	Mount Marshall	86	33	27.01	−0.25	26.76	2.06	4.835 447 1	68 461.61
	[illegible]un	52	31	56.29	+0.24	56.53	2.07	4.735 883 3	54 435.63
				05.75			6.20		
28	Fork	24	41	24.02	−1.40	22.62	1.02	4.652 400 4	44 915.93
	Mount Marshall	134	42	53.03	−0.19	52.84	1.03	4.883 177 2	76 414.75
	Bull Run	20	35	48.13	−0.52	47.61	1.02	4.577 810 2	37 827.72
				05.18			3.07		
29	Fork	87	51	45.06	−1.25	43.81	1.29	4.735 883 3	54 435.63
	Mount Marshall	48	09	26.02	+0.05	26.07	1.30	4.608 327 0	40 581.40
	Clark	43	58	54.95	−0.94	54.01	1.30	4.577 810 3	37 827.73
				06.03			3.89		
30	Fork	63	10	21.04	+0.15	21.19	2.34	4.835 447 1	68 461.61
	Bull Run	31	56	08.16	+0.76	08.92	2.34	4.608 326 9	40 581.39
	Clark	84	53	37.40	−0.48	36.92	2.35	4.883 177 2	76 414.75
				06.60			7.03		
31	Humpback	27	01	48.28	+1.04	49.32	2.46	4.608 326 9	40 581.39
	Fork	98	41	42.28	+0.67	42.95	2.47	4.945 819 1	88 271.22
	Clark	54	16	32.80	+2.32	35.12	2.46	4.860 307 4	72 494.89
				03.36			7.39		
32	Spear	32	08	11.61	+0.49	12.10	2.13	4.860 307 4	72 494.89
	Humpback	128	45	52.84	+0.11	52.95	2.14	5.026 395 5	106 266.29
	Fork	19	05	61.45	−0.10	61.35	2.13	4.649 283 4	44 594.72
				05.90			6.40		

(*d*) *Adjusted triangles, Maryland, Virginia, and West Virginia*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
33	Spear	54	06	29·41	+0·61	30·02	3·26	4·945 819 1	88 271·22
	Humpback	101	44	04·56	−0·93	03·63	3·27	5·028 099 9	106 684·15
	Clark	24	09	37·37	−1·23	36·14	3·26	4·649 283 4	44 594·72
				11·34			9·79		
34	Spear	21	58	17·80	+0·12	17·92	3·59	4·608 326 9	581·39
	Fork	79	35	40·83	+0·77	41·60	3·59	5·028 100 0	106 684·17
	Clark	78	26	10·17	+1·08	11·25	3·59	5·026 395 5	106 266·29
				08·80			10·77		
35	Slate Springs	65	23	08·60	+1·54	10·14	3·46	4·860 307 4	72 494·89
	Fork	57	17	20·00	+1·17	21·17	3·47	4·826 684 6	67 094·14
	Humpback	57	19	38·19	+0·90	39·09	3·47	4·826 871 0	67 122·94
				06·79			10·40		
36	Elliott Knob	49	20	19·32	−1·00	18·32	2·19	4·826 871 0	67 122·94
	Slate Springs	103	56	57·80	+0·82	58·62	2·20	4·933 878 8	85 877·38
	Fork	26	42	49·46	+0·18	49·64	2·19	4·599 631 8	39 776·98
				06·58			6·58		
37	Elliott Knob	106	52	21·83	+0·58	22·41	1·40	4·826 684 6	67 094·14
	Slate Springs	38	33	49·20	−0·72	48·48	1·41	4·640 544 0	43 706·30
	Humpback	34	33	52·86	+0·47	53·33	1·41	4·599 631 7	39 776·97
				03·89			4·22		
38	Elliott Knob	57	32	02·51	+1·58	04·09	2·68	4·860 307 4	72 494·89
	Fork	30	34	30·54	+0·99	31·53	2·68	4·640 543 8	43 706·27
	Humpback	91	53	31·05	+1·37	32·42	2·68	4·933 878 7	85 877·36
				04·10			8·04		
39	Tobacco Row	59	27	05·42	−1·08	04·34	1·37	4·649 283 4	44 594·72
	Humpback	46	51	42·66	−1·31	41·35	1·37	4·577 326 2	37 785·59
	Spear	73	41	19·08	−0·66	18·42	1·37	4·696 339 5	49 698·07
				07·16			4·11		
40	Bald Knob	27	39	43·34	+0·08	43·42	1·78	4·640 543 9	43 706·28
	Elliott Knob	117	11	47·35	−0·69	46·66	1·78	4·922 915 3	83 736·60
	Humpback	35	08	36·48	−1·21	35·27	1·79	4·733 925 0	54 190·73
				07·17			5·35		
41	Bald Knob	36	19	14·75	+0·60	15·35	2·96	4·696 339 5	49 698·07
	Humpback	57	20	16·97	+1·04	18·01	2·97	4·849 042 8	70 638·72
	Tobacco Row	86	20	34·03	+1·51	35·54	2·97	4·922 915 2	83 736·58
				05·75			8·90		

(*a*) *Adjusted triangles, Maryland, Virginia, and West Virginia*—Continued.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
42	Paddy	41	33	26·54	−1·10	25·44	1·47	4·599 631 7	39 776·97
	Slate Springs	46	40	33·81	+0·24	34·05	1·47	4·639 704 4	43 621·88
	Elliott Knob	91	46	05·37	−0·46	04·91	1·46	4·777 675 5	59 934·31
				05·72			4·40		
43	Paddy	50	53	11·97	+0·63	12·60	3·39	4·826 684 6	67 094·14
	Slate Springs	85	14	23·01	−0·48	22·53	3·40	4·935 382 6	86 175·26
	Humpback	43	52	35·76	−0·71	35·05	3·39	4·777 675 5	59 934·31
				10·74			10·18		
44	Paddy	9	19	45·43	+1·73	47·16	0·51	4·640 543 9	43 706·28
	Elliott Knob	161	21	32·80	−0·13	32·67	0·52	4·935 382 5	86 175·24
	Humpback	9	18	42·90	−1·18	41·72	0·52	4·639 704 3	43 621·87
				01·13			1·55		
45	Paddy	82	49	60·32	+1·07	61·39	1·40	4·733 925 0	54 190·73
	Elliott Knob	44	09	45·45	+0·57	46·02	1·39	4·580 373 6	38 051·66
	Bald Knob	53	00	16·88	−0·11	16·77	1·39	4·639 704 3	43 621·87
				02·65			4·18		
46	Paddy	73	30	14·89	−0·65	14·24	2·66	4·922 915 2	83 736·58
	Humpback	25	49	53·58	−0·02	53·56	2·66	4·580 373 6	38 051·66
	Bald Knob	80	39	60·22	-0·03	60·19	2·67	4·935 382 3	86 175·20
				08·69			7·99		
47	Briery	13	57	59·88	+0·14	60·02	0·92	4·639 704 3	43 621·87
	Paddy	150	00	39·74	+1·15	40·89	0·92	4·955 875 6	90 339·07
	Elliott Knob	16	01	22·13	−0·28	21·85	0·92	4·697 983 3	49 886·53
				01·75			2·76		
48	Briery	44	57	20·83	+0·74	21·57	1·48	4·580 373 6	38 051·66
	Paddy	67	10	39·42	+0·08	39·50	1·48	4·695 819 4	49 638·59
	Bald Knob	67	52	02·85	+0·52	03·37	1·48	4·697 983 3	49 886·53
				03·10			4·44		
49	Briery	30	59	20·95	+0·60	21·55	1·95	4·733 925 0	54 190·73
	Elliott Knob	28	08	23·32	+0·85	24·17	1·95	4·695 819 5	49 638·60
	Bald Knob	120	52	19·73	+0·41	20·14	1·96	4·955 875 7	90 339·09
				04·00			5·86		
50	Keeney	17	50	07·22	+0·01	07·23	1·30	4·697 983 3	49 886·53
	Briery	143	33	59·75	+0·50	60·25	1·31	4·985 576 5	96 733·41
	Paddy	18	35	56·55	−0·12	56·43	1·30	4·715 574 4	51 948·67
				03·52			3·91		
51	Keeney	39	34	30·26	+0·48	30·74	2·16	4·695 819 4	49 638·59
	Briery	98	36	38·92	−0·24	38·68	2·15	4·886 701 5	77 037·38
	Bald Knob	41	48	57·15	−0·10	57·05	2·16	4·715 574 3	51 948·66
				06·33			6·47		

(*d*) *Adjusted triangles, Maryland, Virginia, and West Virginia*—Completed.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
52	Keeney	21	44	23·04	+0·47	23·51	2·34	4·580 373 6	38 051·66
	Paddy	48	34	42·87	+0·20	43·07	2·34	4·886 701 4	77 037·36
	Bald Knob	109	40	60·00	+0·43	60·43	2·33	4·985 576 3	96 733·37
				05·91			7·01		
53	Beech	112	05	43·17	−0·85	42·32	0·70	4·715 574 3	51 948·66
	Briery	43	32	19·97	−0·73	19·24	0·70	4·586 819 2	38 620·62
	Keeney	24	21	60·95	−0·41	60·54	0·70	4·364 201 5	23 131·38
				04·09			2·10		
54	Ivy	26	09	45·77	+0·54	46·31	2·21	4·586 819 2	38 620·62
	Beech	52	14	34·52	+0·25	34·77	2·22	4·840 426 0	69 251·00
	Keeney	101	35	44·87	+0·70	45·57	2·22	4·933 509 7	85 804·43
				05·16			6·65		
55	Summersville	20	52	15·90	+0·59	16·49	0·43	4·364 201 5	23 131·38
	Briery	27	18	53·06	+1·21	54·27	0·43	4·474 126 2	29 793·82
	Beech	131	48	49·92	+0·62	50·54	0·44	4·684 764 9	48 391·04
				58·88			1·30		
56	Summersville	95	56	58·09	−0·05	58·04	1·95	4·933 509 7	85 804·43
	Beech	63	50	52·39	−0·03	52·36	1·94	4·888 948 7	77 437·03
	Ivy	20	12	15·48	−0·05	15·43	1·94	4·474 126 3	29 793.83
				05·96			5·83		

(*e*) *Precision of the Allegheny series of triangles.*

For a fair estimate of the precision of the Allegheny series of triangles, we make use of the mean error m of an adjusted angle, where—

$$m = \sqrt{\frac{2\,[pvv]}{c}} \quad \text{and} \quad p = 1$$

For the eastern part, we have—

$$m = \sqrt{\frac{2 \times 4{\cdot}538}{22}} = \pm 0''{\cdot}64$$

for the western part we have—

$$m = \sqrt{\frac{2 \times 20{\cdot}878}{33}} = \pm 1''{\cdot}13$$

and for both together—

$$m = \sqrt{\frac{2 \times 25{\cdot}416}{55}} = \pm 0''{\cdot}96$$

The probable error in length of any side of the triangulation arising from the angular measures may be computed by means of the usual formulae—

$$e_{a_n} = 0{\cdot}674\,5\ m\sqrt{u_{a_n}} \text{ and } u_{a_n} = \tfrac{2}{3}\,(\delta_{a_n})^{-2}\ \Sigma_{a1}^{an}\ [\delta_A^2 + \delta_A\,\delta_B + \delta_B^2]$$

To this must be added the probable error due to that of the side of the base net.

We select the side Fork to Clark, since it divides the series of triangles into two nearly equal parts. Starting from the side Webb to Marriott of the Kent Island Base Net, we have $\delta_{a_n} = 10{\cdot}7$ in units of the sixth place of decimals in the logarithm of the side Fork to Clark, $\Sigma = 128{\cdot}5$ (8 triangles), $e_{a_n} = \pm 0{\cdot}375$ metre, $e_b = \pm 0{\cdot}362$ metre, and $e_1 = \pm 0{\cdot}521$ metre. Starting from the side Ivy to Summersville of the St. Albans Base Net $\Sigma = 133{\cdot}7$ (9 triangles), $e_{a_n} = \pm 0{\cdot}680$ metre, $e_b = \pm 0{\cdot}252$ metre, and $e_2 = \pm 0{\cdot}725$ metre.

For the probable error of the side Fork to Clark as a line in the adjusted triangulation $e = \dfrac{e_1 e_2}{\sqrt{e_1^2 + e_2^2}} = \pm 0{\cdot}423$ metre.

This is about $\frac{1}{96\,000}$ part of the length of the side.

The effect on the arc for the two sections will be with sufficient accuracy—

	Distance.	Probable errors.		Average.	
	km.				*m.*
Webb-Marriott to Fork-Clark	136	$\frac{1}{112\,000}$	$\frac{1}{98\,000}$	$\frac{1}{103\,000}$	$\pm 1{\cdot}32$
Fork-Clark to Ivy-Summersville	257	$\frac{1}{98\,000}$	$\frac{1}{161\,000}$	$\frac{1}{120\,000}$	$\pm 2{\cdot}14$
				Sum	$\pm 3{\cdot}46$

The above distances are measured along the thirty-ninth parallel between the projections of the middle points of the terminal sides.

(3) THE OHIO SERIES OF TRIANGLES.

1883–84–85–86–87, 1889–90.

(*a.*) *Introduction.*

This branch of the triangulation after leaving the mountainous part of West Virginia enters the Ohio Valley and follows the same more or less closely and with about uniform width up to its western end at the Holton Base figure. The work was in charge of Assistant A. T. Mosman, and was carried out between the years 1883 and 1890; measured along the middle of the triangulation its extent between the two base-net lines is about 330 kilometres, or 205 statute miles.

The following remarks were communicated by Assistant Mosman:

From the St. Albans Base in the Kanawha Valley the triangulation passes over heavily wooded country to the Ohio Valley and then down this valley to the vicinity of Cincinnati, having stations in both Ohio and Kentucky. This was a very difficult country to triangulate, as the tops of the numerous ridges, all heavily wooded, were nearly of the same height, forming a plateau in which numerous streams had cut channels. The country was thinly settled; roads, all in the valleys of the streams, were few and very rough. It was neces ary to build signals here varying from 30 to 80 feet in height to get lines of 20 miles in length, and heliotropes had to be used on lines longer than 12 or 15 miles. From near Cincinnati the series passed through Kentucky and Indiana, leaving the valley of the Ohio

River; in the latter State it passed through an almost level country very heavily wooded to the Holton Base line, which is located on a high ridge. This is a farming and lumber country with forests over 100 feet high for miles in every direction; here signals of from 100 to 150 feet in height were necessary, and heliotropes were used on lines over 10 miles in length unless the sun was at the observer's back, in which case a pole with a lozenge target could be observed on.

The observers habitually observed their directions with the circle of the theodolites in 17 positions with 2 series in each; in case the series contained only part of the directions they were multiplied until a sufficient number of series was obtained.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments.*

Piney, Cabell County, West Virginia. August 21 to September 4, 1883. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers. December 16 to December 21, 1891. 30-centimetre theodolite, No. 118. W. B. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base net adjustment.	Corrections from base net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Pigeon	0	00	00·00	±0·08	−0·17		59·83
3	Davis	66	33	51·05	0·12		−0·09	50·96
4	Gebhardt	117	16	06·01	0·08		−0·32	05·69
	Simms	265	09	53·84	0·11	−0·28		53·56
	Holmes	270	36	07·62	0·09	+0·21		07·83
	Coal	293	29	60·19	0·09	−0·39		59·80
	Table Rock	304	16	56·84	0·13	+0·45		57·29
	Big Rocks	310	51	38·03	0·11	+0·18		38·21
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·66.

Pigeon, Lincoln County, West Virginia. July 21 to August 5, 1883. 50-centimetre theodolite, No. 114. A. T. Mosman and W. B. Fairfield, observers.

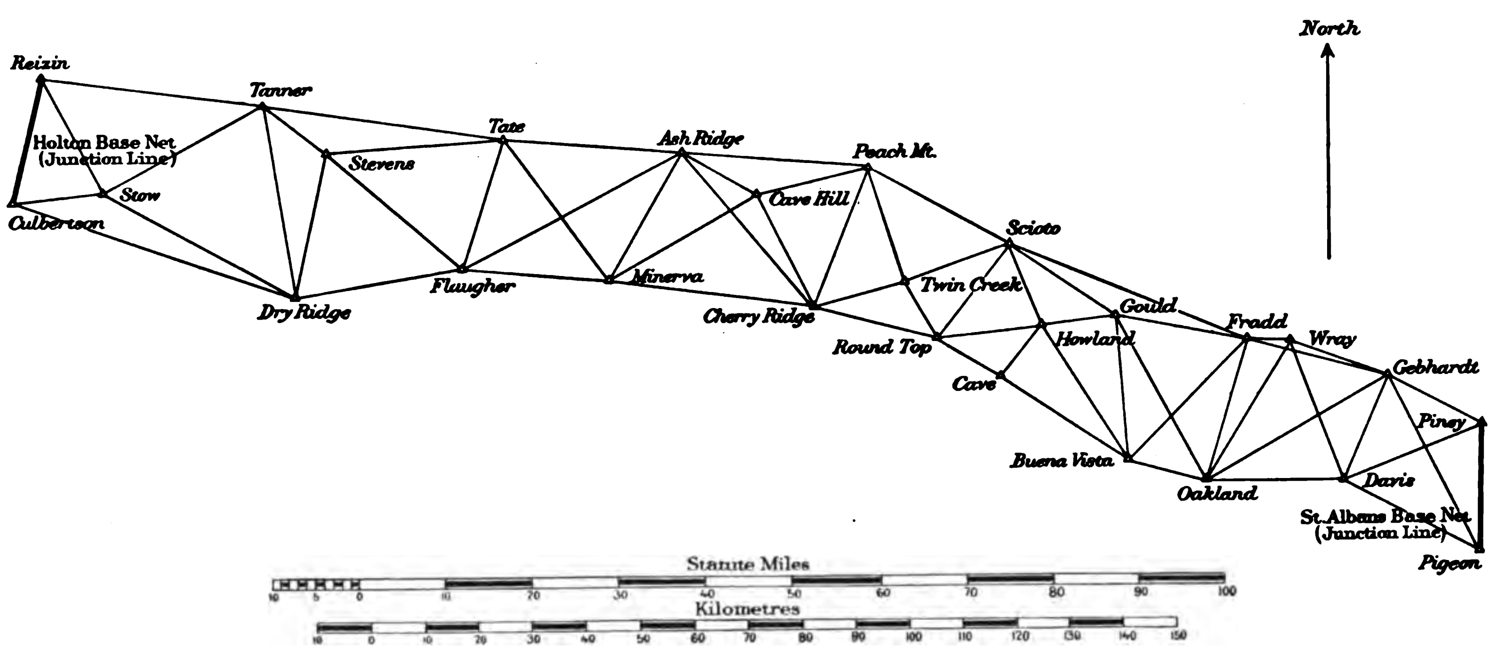
No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base net adjustment.	Corrections from base net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Piney	0	00	00·00	±0·09	−0·12		59·88
	Big Rocks	41	27	17·14	0·13	+0·20		17·34
	Table Rock	94	31	34·23	0·10	+0·32		34·55
	Ivy	132	07	07·02	0·10	−0·40		06·62
1	Davis	296	48	34·59	0·12		−0·03	34·56
2	Gebhardt	332	13	32·79	0·12		+0·59	33·38
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·72.

ST. ALBANS BASE NET TO HOLTON BASE NET

OHIO SERIES

W. VA., O., KY., AND IND.



(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments*—Continued.

Gebhardt, Cabell County, West Virginia. October 28 to November 9, 1883. 30-centimetre theodolite, No. 118. Telescope above ground 15·27 metres. A. T. Mosman, observer. September 7 to September 9, 1884. 30-centimetre theodolite, No. 118. Telescope above ground 15·27 metres. A. T. Mosman, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
10	Piney	0	00	00·00	±0·11	+0·20	00·20
11	Pigeon	34	57	29·07	0·16	−0·18	28·89
12	Davis	85	02	10·85	0·11	−0·20	10·65
13	Oakland	122	59	04·54	0·22	+0·41	04·95
14	Fradd	167	05	29·86	0·15	−0·53	29·33
15	Wray	173	03	19·07	0·09	+0·30	19·37

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·89.

Davis, Cabell County, West Virginia. October 8 to October 18, 1883. 30-centimetre theodolite, No. 118. Telescope above ground 25·91 metres. A. T. Mosman, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
7	Gebhardt	0	00	00·00	±0·13	+0·14	00·14
8	Piney	44	15	35·71	0·13	+0·32	36·03
9	Pigeon	94	30	21·33	0·11	−0·20	21·13
5	Oakland	248	55	19·65	0·12	−0·51	19·14
6	Wray	316	58	17·75	0·13	+0·25	18·00

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·78.

Wray, Lawrence County, Ohio. August 5 to September 3, 1884. 30-centimetre theodolite, No. 118. Telescope above ground 25·91 metres. A. T. Mosman, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
16	Gebhardt	0	00	00·00	±0·09	+0·27	00·27
17	Davis	48	57	10·88	0·10	−0·39	10·49
18	Oakland	100	32	59·95	0·11	−0·44	59·51
19	Fradd	159	11	36·04	0·13	+0·56	36·60

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·70.

Oakland, Boyd County, Kentucky. September 18 to October 2, 1884. 30-centimetre theodolite, No. 118. Telescope above ground 15·09 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
20	Buena Vista	0	00	00·00	±0·09	−0·01	$\overline{59}$·99
21	Gould	47	46	21·92	0·09	−0·33	21·59
22	Fradd	93	11	00·23	0·12	+0·04	00·27
23	Wray	107	33	09·48	0·10	+0·23	09·71
24	Gebhardt	136	55	58·01	0·11	−0·47	57·54
25	Davis	167	54	23·01	0·13	+0·54	23·55

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·73.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments*—Continued.

Fradd, Lawrence County, Ohio. August 5 to August 14, 1885. 30-centimetre theodolite, No. 135. Telescope above ground 14·17 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
26	Wray	0	00	00·00	±0·15	−0·32	59·68
27	Gebhardt	14	50	33·64	0·24	−0·18	33·46
28	Oakland	106	59	13·41	0·24	+0·27	13·68
29	Buena Vista	133	55	54·45	0·22	+0·59	55·04
30	Gould	190	31	27·12	0·22	−0·23	26·89
31	Scioto	202	13	50·67	0·23	−0·14	50·53

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·37.

Buena Vista, Greenup County, Kentucky. October 11 to October 21, 1884. 30-centimetre theodolite, No. 118. Telescope above ground 1·83 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
36	Oakland	0	00	00·00	±0·09	+0·04	00·04
32	Cave	200	43	46·49	0·14	+0·28	46·77
33	Howland	223	50	50·02	0·10	+0·12	50·14
34	Gould	250	30	50·14	0·10	+0·30	50·44
35	Fradd	300	07	41·42	0·06	−0·73	40·69

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·66.

Gould, Scioto County, Ohio. July 27 to August 5, 1885. 30-centimetre theodolite, No. 118. Telescope above ground 20·27 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
40	Howland	0	00	00·00	±0·13	−0·02	59·98
	Springville	36	55	04·14	0·09		
41	Scioto	40	45	59·69	0·13	−0·11	59·58
	Azimuth Mark	96	50	45·05	0·17		
37	Fradd	196	32	45·93	0·12	+0·25	46·18
38	Oakland	247	35	55·86	0·13	+0·14	56·00
39	Buena Vista	270	20	25·99	0·13	−0·25	25·74

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·80.

Howland, Greenup County, Kentucky. August 31 to September 7, 1885. 30-centimetre theodolite, No. 135. Telescope above ground 20·27 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
42	Gould	0	00	00·00	±0·22	+0·06	00·06
43	Buena Vista	63	40	26·41	0·25	+0·06	26·47
44	Cave	133	03	37·38	0·20	+0·83	38·21
45	Round Top	178	48	19·30	0·19	−0·39	18·91
46	Scioto	255	17	51·01	0·22	−0·55	50·46
	Springville	264	29	19·76	0·46		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·33.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments*—Continued.

Scioto, Scioto County, Ohio. November 11 to November 30, 1885. 30-centimetre theodolite, No. 118. Telescope above ground 30·94 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
49	Howland	0	00	00·00	±0·09	+0·63	00·63
50	Round Top	59	14	33·78	0·14	−0·65	33·13
51	Twin Creek	91	28	35·78	0·16	−0·09	35·69
52	Peach Mount	138	37	38·39	0·18	−0·17	38·22
	North Meridian	308	32	00·58	0·23		
47	Fradd	312	57	18·65	0·21	+0·28	18·93
48	Gould	325	28	09·30	0·15	0·00	09·30
	Springville	336	14	25·12	0·18		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·90.

Cave, Greenup County, Kentucky. August 27, to August 29, 1885. 30-centimetre theodolite, No. 135. Telescope above ground 9·60 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
53	Round Top	0	00	00·00	±0·15	+1·25	01·25
54	Howland	96	24	31·10	0·29	−0·83	30·27
55	Buena Vista	183	54	16·45	0·22	−0·42	16·03

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·33.

Round Top, Lewis County, Kentucky. October 22 to November 8, 1885. 30-centimetre theodolite, No. 135. Telescope above ground 1·68 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
57	Twin Creek	0	00	00·00	±0·17	+0·31	00·31
58	Scioto	70	08	47·80	0·21	+0·73	48·53
	Springville	86	21	18·82	0·29		
59	Howland	114	24	44·79	0·17	+0·46	45·25
60	Cave	152	15	37·27	0·23	−1·32	35·95
56	Cherry Ridge	314	29	02·28	0·20	−0·18	02·10

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·29.

Peach Mount, Adams County, Ohio. September 9 to September 25, 1886. 30-centimetre theodolite, No. 118. Telescope above ground 15·24 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
66	Twin Creek	0	00	00·00	±0·10	−0·40	$\overline{59}$·60
67	Cherry Ridge	40	05	57·46	0·09	−0·15	57·31
	West Union Children's Home	71	43	56·97	0·22		
68	Cave Hill	94	11	06·28	0·14	+0·36	06·64
69	Ash Ridge	112	51	36·99	0·13	−0·20	36·79
65	Scioto	316	30	42·44	0·17	+0·39	42·83

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·81.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments*—Continued.

Cherry Ridge, Lewis County, Kentucky. October 12 to October 20, 1886. 30-centimetre theodolite, No. 118. Telescope above ground 1·68 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
74	Twin Creek	0	00	00·00	±0·08	−0·46	59·54
75	Round Top	28	10	13·41	0·10	+0·34	13·75
70	Minerva	203	01	17·63	0·10	+0·08	17·71
71	Ash Ridge	245	30	43·53	0·11	−0·02	43·51
72	Cave Hill	259	25	04·63	0·13	−0·17	04·46
	West Union Children's Home	267	48	36·13	0·22		
73	Peach Mount	306	48	16·09	0·12	+0·24	16·33

Probable error of a single observation of a direction ($D.$ and $R.$) = ±0″·67.

Cave Hill, Adams County, Ohio. September 29 to October 8, 1886. 30-centimetre theodolite, No. 118. Telescope above ground 1·68 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
76	Peach Mount	0	00	00·00	±0·09	−0·27	59·73
	West Union Children's Home	62	10	03·40	0·21		
77	Cherry Ridge	78	31	39·56	0·12	+0·18	39·74
78	Minerva	164	51	28·82	0·14	0·00	28·82
79	Ash Ridge	223	57	43·24	0·15	+0·09	43·33

Probable error of a single observation of a direction ($D.$ and $R.$) = ±0″·79.

Ash Ridge, Brown County, Ohio. June 22 to July 5, 1887. 30-centimetre theodolite, No. 118. Telescope above ground 27·89 metres. A. T. Mosman, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
81	Cave Hill	0	00	00·00	±0·13	−0·07	59·93
82	Cherry Ridge	20	39	35·83	0·19	+0·09	35·92
83	Minerva	91	12	51·00	0·18	+0·25	51·25
84	Flaugher	123	28	35·97	0·13	−0·32	35·65
85	Tate	154	15	57·66	0·17	−0·09	57·57
80	Peach Mount	334	42	45·76	0·16	+0·13	45·89

Probable error of a single observation of a direction ($D.$ and $R.$) = ±1″·01.

Minerva, Mason County, Kentucky. July 11 to July 31, 1887. 30-centimetre theodolite, No. 118. Telescope above ground 14·17 metres. A. T. Mosman, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
88	Ash Ridge	0	00	00·00	±0·09	−0·01	59·99
89	Cave Hill	29	40	55·14	0·17	+0·12	55·26
90	Cherry Ridge	66	57	21·54	0·16	−0·23	21·31
	Brookville Methodist Church spire	225	40	16·92	0·25		
86	Flaugher	244	15	56·50	0·16	−0·11	56·39
	Felicity Town Hall	282	29	03·84	0·29		
87	Tate	293	11	39·27	0·15	+0·23	39·50
	Azimuth Mark	333	11	35·09	0·10		

Probable error of a single observation of a direction ($D.$ and $R.$) = ±0″·91.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments*—Continued.

Twin Creek, Adams County, Ohio. August 28 to September 1, 1886. 30-centimetre theodolite, No. 118. Telescope above ground 24·84 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
62	Round Top	0	00	00·00	±0·14	−0·41	59·59
63	Cherry Ridge	106	18	47·42	0·14	+0·28	47·70
64	Peach Mount	193	01	07·60	0·11	+0·23	07·83
61	Scioto	282	22	49·83	0·11	−0·09	49·74

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·78.

Tate, Clermont County, Ohio. September 8 to October 11, 1887. 30-centimetre theodolite, No. 118. Telescope above ground 39·18 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	Approximate probable error ″	Corrections from figure adjustment ″	Final seconds in triangulation ″
	Felicity Town Hall	0	00	00·00	±0·08		
93	Flaugher	36	43	20·35	0·12	+0·03	20·38
94	Stevens	102	54	35·45	0·15	−0·35	35·10
	Alexandria Court-house	111	38	43·21	0·16		
95	Tanner	114	42	11·53	0·12	+0·44	11·97
	Cold Spring spire	125	32	08·20	0·32		
91	Ash Ridge	289	54	58·98	0·12	+0·53	59·51
92	Minerva	340	03	35·39	0·13	−0·65	34·74

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·79.

Flaugher, Pendleton County, Kentucky. October 16 to November 20, 1887. 30 centimetre theodolite, No. 135. Telescope above ground 27·89 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	Approximate probable error ″	Corrections from figure adjustment ″	Final seconds in triangulation ″
	Felicity Town Hall	0	00	00·00	±0·10		
99	Ash Ridge	18	26	45·62	0·36	−0·58	45·04
100	Minerva	50	26	58·34	0·14	−0·42	58·76
	Brooksville spire	64	59	11·87	0·38		
	Williamstown Court-house	205	24	46·39	0·29		
96	Dry Ridge	214	30	27·43	0·19	−0·17	27·26
	Fiskburg spire	246	14	55·00	0·48		
97	Stevens	267	08	37·60	0·17	+0·05	37·65
98	Tate	336	02	25·55	0·13	+0·28	25·83

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·05.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments*—Continued.

Stevens, Kenton County, Kentucky. October 15 to November 5, 1887. 30-centimetre theodolite, No. 118. Telescope above ground 16·31 metres. A. T. Mosman, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
109	Tanner	0	00	00·00	±0·09	+0·76	00·76
	Alexandria Court-house	124	25	23·60	0·15		
106	Tate	141	07	51·13	0·15	+0·06	51·19
107	Flaugher	186	02	50·32	0·17	−0·14	50·18
	Morning View spire	212	18	47·86	0·18		
	Fiskburg spire	231	20	55·57	0·33		
108	Dry Ridge	246	16	15·69	0·14	−0·68	15·01

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·84.

Dry Ridge, Grant County, Kentucky. August 25 to September 9, 1889. 30-centimetre theodolite, No. 118. Telescope above ground 27·89 metres. A. T. Mosman, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
	Williamstown, Grant County, court-house vane rod	0	00	00·00	±0·08		
101	Culbertson	125	41	28·92	0·10	−0·52	28·40
102	Stow	135	46	33·36	0·18	−0·21	33·15
103	Tanner	187	37	08·12	0·15	+0·01	08·13
104	Stevens	209	26	31·37	0·12	+0·52	31·89
	Morning View church spire	232	31	55·55	0·35		
105	Flaugher	276	34	58·46	0·17	+0·19	58·65

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·84.

Tanner, Boone County, Kentucky. July 19 to August 16, 1889. 30-centimetre theodolite, No. 118. Telescope above ground 41·61 metres. A. T. Mosman and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
111	Stevens	0	00	00·00	±0·08	−0·93	$\overline{59}$·07
112	Dry Ridge	44	26	50·32	0·14	+0·20	50·52
113	Stow	115	52	23·37	0·15	−0·39	22·98
114	Reizin	151	53	14·47	0·12	+1·10	15·57
	Price's Hill railroad incline building cupola	269	56	54·46	0·20		
	Convent belfry	282	42	03·87	0·41		
	Lookout House flagstaff	289	33	28·26	0·18		
	Cold Spring, larger spire	315	26	05·91	0·29		
110	Tate	332	55	25·57	0·17	+0·02	25·59
	Alexandria Court-house	335	48	01·68	0·33		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·94.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments*—Completed.

Stow, Switzerland County, Indiana. May 28 to June 5, 1890. 30-centimetre theodolite, No. 118. Telescope above ground 21·18 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
116	Reizin	0	00	00·00	±0·09	+0·17	00·17
117	Tanner	90	31	47·94	0·08	+0·38	48·32
118	Dry Ridge	147	15	43·63	0·13	+0·25	43·88
115	Culbertson	292	13	48·91	0·14	−0·81	48·10

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·68.

Reizin, Ripley County, Indiana. September 21 to September 28, 1889. 30-centimetre theodolite, No. 118. Telescope above ground 35·81 metres. A. T. Mosman, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Glasgow	0	00	00·00	±0·13	−0·14		59·86
121	Tanner	161	59	13·94	0·13		−1·03	12·91
122	Stow	215	26	34·50	0·12		−0·15	34·35
	Culbertson	255	56	07·78	0·14	−0·15		07·63
	Correct	318	50	47·95	0·12	+0·29		48·24
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·79.

Culbertson, Switzerland County, Indiana. June 7 to June 19, 1890. 30-centimetre theodolite, No. 118. Telescope above ground 35·81 metres. W. B. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Reizin	0	00	00·00	±0·08	−0·42		59·58
119	Stow	71	44	14·42	0·11		+0·82	15·24
120	Dry Ridge	96	41	06·92	0·13		+0·38	07·30
	Mud Lick	265	16	50·27	0·10	−0·04		50·23
	Correct	328	10	57·51	0·10	+0·46		57·97
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·64.

(*c*) *Figure adjustment.*

Observation equations.

1	$0 = +0{\cdot}58 - (1) + (3) - (8) + (9)$
2	$0 = +1{\cdot}29 - (2) + (4) - (10) + (11)$
3	$0 = +0{\cdot}46 - (3) + (4) - (7) + (8) - (10) + (12)$
4	$0 = +0{\cdot}28 - (6) + (7) - (12) + (15) - (16) + (17)$
5	$0 = -2{\cdot}28 - (5) + (7) - (12) + (13) - (24) + (25)$
6	$0 = -1{\cdot}04 - (5) + (6) - (17) + (18) - (23) + (25)$
7	$0 = -1{\cdot}77 - (18) + (19) - (22) + (23) - (26) + (28)$
8	$0 = +1{\cdot}00 - (13) + (14) - (22) + (24) - (27) + (28)$
9	$0 = -1{\cdot}14 - (20) + (22) - (28) + (29) - (35) + (36)$
10	$0 = +2{\cdot}$[illegible]$5 - (29) + (30) - (37) + (39) - (34) + (35)$
11	$0 = +0{\cdot}9$[illegible]$ - (20) + (21) - (34) + (36) - (38) + (39)$
12	$0 = -0{\cdot}41 - (33) + (34) - (39) + (40) - (42) + (43)$
13	$0 = -1{\cdot}15 - (40) + (41) + (42) + (46) - (48) + (49)$
14	$0 = -1{\cdot}02 - (32) + (33) - (43) + (44) - (54) + (55)$
15	$0 = +5{\cdot}08 - (44) + (45) - (53) + (54) - (59) + (60)$
16	$0 = +1{\cdot}72 - (45) + (46) - (49) + (50) - (58) - (59)$
17	$0 = -0{\cdot}17 - (30) + (31) + (37) - (41) - (47) + (48)$
18	$0 = -0{\cdot}66 - (50) + (51) - (57) + (58) - (61) + (62)$
19	$0 = +1{\cdot}19 - (51) + (52) + (61) - (64) - (65) - (66)$
20	$0 = +0{\cdot}51 - (63) + (64) - (66) + (67) - (73) + (74)$
21	$0 = -1{\cdot}98 - (56) + (57) - (62) + (63) - (74) + (75)$
22	$0 = -0{\cdot}18 - (67) + (69) - (71) + (73) - (80) + (82)$
23	$0 = +1{\cdot}12 - (68) + (69) + (76) - (79) - (80) + (81)$
24	$0 = +0{\cdot}16 - (70) + (71) - (82) + (83) - (88) + (90)$
25	$0 = +0{\cdot}78 - (70) + (72) - (77) + (78) - (89) + (90)$
26	$0 = -0{\cdot}54 - (78) + (79) - (81) + (83) - (88) + (89)$
27	$0 = +1{\cdot}76 - (83) + (85) - (87) + (88) - (91) + (92)$
28	$0 = -0{\cdot}54 - (83) + (84) - (86) + (88) - (99) + (100)$
29	$0 = -1{\cdot}16 - (86) + (87) - (92) + (93) - (98) + (100)$
30	$0 = +0{\cdot}34 - (93) + (94) - (97) + (98) - (106) + (107)$
31	$0 = +0{\cdot}65 - (96) + (97) - (104) + (105) - (107) + (108)$
32	$0 = +0{\cdot}86 - (94) + (95) + (106) - (109) - (110) + (111)$
33	$0 = -3{\cdot}08 - (103) + (104) - (108) + (109) - (111) + (112)$
34	$0 = +0{\cdot}50 - (102) + (103) - (112) + (113) - (117) + (118)$
35	$0 = -2{\cdot}58 - (113) + (114) - (116) + (117) - (121) + (122)$
36	$0 = +1{\cdot}19 - (101) + (102) + (115) - (118) - (119) + (120)$
37	$0 = -1{\cdot}95 - (115) + (116) + (119) - (122)$
38	$0 = +2{\cdot}6 + 1{\cdot}07(1) - 4{\cdot}00(2) + 2{\cdot}16(7) - 3{\cdot}91(8) + 1{\cdot}75(9) + 2{\cdot}83(10) - 3{\cdot}01(11) + 0{\cdot}18(12)$
39	$0 = -2{\cdot}7 + 2{\cdot}63(12) - 2{\cdot}70(13) + 0{\cdot}07(15) + 1{\cdot}83(16) - 3{\cdot}50(17) + 1{\cdot}67(18) + 1{\cdot}20(23) - 3{\cdot}51(24) + 2{\cdot}31(25)$
40	$0 = -11{\cdot}2 + 1{\cdot}76(13) - 20{\cdot}16(14) + 18{\cdot}40(15) + 8{\cdot}22(22) - 11{\cdot}96(23) + 3{\cdot}74(24) + 8{\cdot}58(26) - 7{\cdot}94(27) - 0{\cdot}64(28)$
41	$0 = +2{\cdot}5 + 3{\cdot}90(28) - 4{\cdot}14(29) + 0{\cdot}24(30) - 0{\cdot}75(34) - 1{\cdot}22(35) + 1{\cdot}97(36) + 1{\cdot}70(37) - 6{\cdot}72(38) + 5{\cdot}02(39)$

(c) *Figure adjustment*—Continued.

Observation equations—Completed.

42 $0 = -4{\cdot}4 + 1{\cdot}39(29) - 11{\cdot}55(30) + 10{\cdot}16(31) + 4{\cdot}19(33) - 5{\cdot}98(34) + 1{\cdot}79(35) - 0{\cdot}49(42)$
$+ 1{\cdot}04(43) - 0{\cdot}55(46) + 9{\cdot}49(47) - 12{\cdot}55(48) + 3{\cdot}06(49)$

43 $0 = +7{\cdot}0 + 4{\cdot}93(32) - 9{\cdot}12(33) + 4{\cdot}19(34) + 0{\cdot}01(39) - 2{\cdot}45(40) + 2{\cdot}44(41) + 3{\cdot}06(48)$
$- 4{\cdot}31(49) + 1{\cdot}25(50) - 0{\cdot}24(53) + 0{\cdot}15(54) + 0{\cdot}09(55) + 2{\cdot}16(58) - 4{\cdot}87(59) + 2{\cdot}71(60)$

44 $0 = -3{\cdot}9 + 3{\cdot}34(50) - 5{\cdot}30(51) + 1{\cdot}96(52) + 2{\cdot}07(56) - 2{\cdot}83(57) + 0{\cdot}76(58) + 2{\cdot}22(65)$
$- 4{\cdot}72(66) + 2{\cdot}50(67) + 1{\cdot}58(73) - 5{\cdot}52(74) + 3{\cdot}94(75)$

45 $0 = +0{\cdot}4 + 1{\cdot}52(67) - 7{\cdot}75(68) + 6{\cdot}23(69) + 8{\cdot}51(71) - 10{\cdot}44(72) + 1{\cdot}93(73) + 4{\cdot}46(80)$
$- 10{\cdot}04(81) + 5{\cdot}58(82)$

46 $0 = +3{\cdot}7 + 1{\cdot}52(67) - 7{\cdot}75(68) + 6{\cdot}23(69) + 1{\cdot}39(70) - 3{\cdot}32(72) + 1{\cdot}93(73) + 4{\cdot}46(80)$
$- 4{\cdot}42(81) - 0{\cdot}04(83) + 3{\cdot}70(88) - 6{\cdot}46(89) + 2{\cdot}76(90)$

47 $0 = -2{\cdot}4 + 1{\cdot}07(83) - 3{\cdot}53(84) + 2{\cdot}46(85) + 1{\cdot}83(86) - 2{\cdot}73(87) + 0{\cdot}90(88) + 1{\cdot}72(98)$
$- 2{\cdot}31(99) + 0{\cdot}59(100)$

48 $0 = -11{\cdot}5 + 0{\cdot}93(93) - 11{\cdot}01(94) + 10{\cdot}08(95) + 1{\cdot}60(96) - 2{\cdot}41(97) + 0{\cdot}81(98) + 5{\cdot}26(103)$
$- 6{\cdot}15(104) + 0{\cdot}89(105) + 4{\cdot}12(110) - 6{\cdot}27(111) + 2{\cdot}15(112)$

49 $0 = +2{\cdot}2 + 11{\cdot}84(101) - 13{\cdot}50(102) + 1{\cdot}66(103) + 0{\cdot}70(112) - 3{\cdot}60(113) + 2{\cdot}90(114)$
$- 5{\cdot}23(119) + 4{\cdot}53(120) + 1{\cdot}56(121) - 4{\cdot}03(122)$

50 $0 = -0{\cdot}7 + 1{\cdot}07(1) + 1{\cdot}73(3) - 1{\cdot}73(4) - 0{\cdot}81(5) + 0{\cdot}81(7) - 1{\cdot}75(8) + 1{\cdot}75(9) - 0{\cdot}18(10)$
$+ 0{\cdot}18(12) + 2{\cdot}17(13) - 2{\cdot}17(14) - 0{\cdot}11(20) + 0{\cdot}11(22) - 3{\cdot}51(24) + 3{\cdot}51(25) + 0{\cdot}08(27)$
$- 0{\cdot}08(28) + 1{\cdot}39(29) - 1{\cdot}39(30) + 4{\cdot}19(33) - 4{\cdot}19(34) - 1{\cdot}22(35) + 1{\cdot}22(36) - 0{\cdot}62(37)$
$+ 0{\cdot}62(39) + 2{\cdot}44(40) - 2{\cdot}44(41) - 1{\cdot}04(42) + 1{\cdot}04(43) + 0{\cdot}51(45) - 0{\cdot}51(46) - 3{\cdot}06(48)$
$+ 3{\cdot}06(49) + 1{\cdot}96(51) - 1{\cdot}96(52) + 0{\cdot}76(57) - 2{\cdot}92(58) + 2{\cdot}16(59) - 0{\cdot}47(61) + 0{\cdot}47(62)$
$+ 0{\cdot}12(63) - 0{\cdot}12(64) - 2{\cdot}22(65) + 2{\cdot}22(66) + 1{\cdot}52(67) - 1{\cdot}52(68) + 1{\cdot}39(70) - 1{\cdot}39(72)$
$- 1{\cdot}58(73) + 1{\cdot}58(74) - 0{\cdot}43(76) + 0{\cdot}43(77) + 1{\cdot}26(78) - 1{\cdot}26(79) + 0{\cdot}04(81) + 1{\cdot}03(83)$
$- 1{\cdot}07(85) + 1{\cdot}83(86) - 1{\cdot}83(87) - 2{\cdot}76(89) + 2{\cdot}76(90) - 1{\cdot}76(91) + 1{\cdot}76(92) + 0{\cdot}93(93)$
$- 0{\cdot}93(94) + 1{\cdot}60(96) - 1{\cdot}60(97) - 0{\cdot}59(98) + 0{\cdot}59(100) + 1{\cdot}66(102) - 1{\cdot}66(103)$
$- 0{\cdot}89(104) + 0{\cdot}89(105) - 2{\cdot}11(106) + 2{\cdot}11(107) - 0{\cdot}93(108) + 0{\cdot}93(109) - 2{\cdot}15(111)$
$+ 2{\cdot}15(112) + 2{\cdot}90(113) - 2{\cdot}90(114) - 1{\cdot}39(117) + 1{\cdot}39(118) + 0{\cdot}70(119) - 1{\cdot}56(121)$
$+ 1{\cdot}56(122) + 0{\cdot}86(115 - 0{\cdot}86(116)$

Correlate equations.

$(1) = -C_1 + 1{\cdot}07C_{38} + 1{\cdot}07C_{50}$

$(2) = -C_2 - 4{\cdot}00C_{38}$

$(3) = +C_1 - C_3 + 1{\cdot}73C_{50}$

$(4) = +C_2 + C_3 - 1{\cdot}73C_{50}$

$(5) = -C_5 - C_6 - 0{\cdot}81C_{50}$

$(6) = -C_4 + C_6$

$(7) = -C_3 + C_4 + C_5 + 2{\cdot}16C_{38} - 0{\cdot}81C_{50}$

$(8) = -C_1 + C_3 - 3{\cdot}91C_{38} - 1{\cdot}75C_{50}$

$(9) = +C_1 + 1{\cdot}75C_{38} + 1{\cdot}75C_{50}$

$(10) = -C_2 - C_3 + 2{\cdot}83C_{38} - 0{\cdot}18C_{50}$

$(11) = +C_2 - 3{\cdot}01C_{38}$

$(12) = +C_3 - C_4 - C_5 + 0{\cdot}18C_{38} + 2{\cdot}63C_{39} + 0{\cdot}18C_{50}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

$(13) = +C_5 - C_8 - 2.70C_{39} + 1.76C_{40} + 2.17C_{50}$
$(14) = +C_8 - 20.16C_{40} - 2.17C_{50}$
$(15) = +C_4 + 0.07C_{39} + 18.40C$
$(16) = -C_4 + 1.83C_{39}$
$(17) = +C_4 - C_6 - 3.50C_{39}$
$(18) = +C_6 - C_7 + 1.67C_{39}$
$(19) = +C_7$
$(20) = -C_9 - C_{11} - 0.11C_{50}$
$(21) = +C_{11}$
$(22) = -C_7 - C_8 + C_9 + 8.22C_{40} + 0.11C_{50}$
$(23) = -C_6 + C_7 + 1.20C_{39} - 11.96C_{40}$
$(24) = -C_5 + C_8 - 3.51C_{39} + 3.74C_{40} - 3.51C_{50}$
$(25) = +C_5 + C_6 + 2.31C_{39} + 3.51C_{50}$
$(26) = -C_7 + 8.58C_{40}$
$(27) = -C_8 - 7.94C_{40} + 0.08C_{50}$
$(28) = +C_7 + C_8 - C_9 - 0.64C_{40} + 3.90C_{41} - 0.08C_{50}$
$(29) = +C_9 - C_{10} - 4.14C_{41} + 1.39C_{42} + 1.39C_{50}$
$(30) = +C_{10} - C_{17} + 0.24C_{41} - 11.55C_{42} - 1.39C_{50}$
$(31) = +C_{17} + 10.16C_{42}$
$(32) = -C_{14} + 4.93C_{43}$
$(33) = -C_{12} + C_{14} + 4.19C_{42} - 9.12C_{43} + 4.19C_{50}$
$(34) = -C_{10} - C_{11} + C_{12} - 0.75C_{41} - 5.98C_{42} + 4.19C_{43} - 4.19C_{50}$
$(35) = -C_9 + C_{10} - 1.22C_{41} + 1.79C_{42} - 1.22C_{50}$
$(36) = +C_9 + C_{11} + 1.97C_{41} + 1.22C_{50}$
$(37) = -C_{10} + C_{17} + 1.70C_{41} - 0.62C_{50}$
$(38) = -C_{11} - 6.72C_{41}$
$(39) = +C_{10} + C_{11} - C_{12} + 5.02C_{41} + 0.01C_{43} + 0.62C_{50}$
$(40) = +C_{12} - C_{13} - 2.45C_{43} + 2.44C_{50}$
$(41) = +C_{13} - C_{17} + 2.44C_{43} - 2.44C_{50}$
$(42) = -C_{12} + C_{13} - 0.49C_{42} - 1.04C_{50}$
$(43) = +C_{12} - C_{14} + 1.04C_{42} + 1.04C_{50}$
$(44) = +C_{14} - C_{15}$
$(45) = +C_{15} - C_{16} + 0.51C_{50}$
$(46) = -C_{13} + C_{16} - 0.55C_{42} - 0.51C_{50}$
$(47) = -C_{17} + 9.49C_{42}$
$(48) = -C_{13} + C_{17} - 12.55C_{42} + 3.06C_{43} - 3.06C_{50}$
$(49) = +C_{13} - C_{16} + 3.06C_{42} - 4.31C_{43} + 3.06C_{50}$
$(50) = +C_{16} - C_{18} + 1.25C_{43} + 3.34C_{44}$
$(51) = +C_{18} - C_{19} - 5.30C_{44} + 1.96C_{50}$
$(52) = +C_{19} + 1.96C_{44} - 1.96C_{50}$
$(53) = -C_{15} - 0.24C_{43}$
$(54) = -C_{14} + C_{15} + 0.15C_{43}$
$(55) = +C_{14} + 0.09C_{43}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

$(56) = -C_{21} + 2{\cdot}07C_{44}$

$(57) = -C_{18} + C_{21} - 2{\cdot}83C_{44} + 0{\cdot}76C_{50}$

$(58) = -C_{16} + C_{18} + 2{\cdot}16C_{43} + 0{\cdot}76C_{44} - 2{\cdot}92C_{50}$

$(59) = -C_{15} + C_{16} - 4{\cdot}87C_{43} + 2{\cdot}16C_{50}$

$(60) = +C_{15} + 2{\cdot}71C_{43}$

$(61) = -C_{18} + C_{19} - 0{\cdot}47C_{50}$

$(62) = +C_{18} - C_{21} + 0{\cdot}47C_{50}$

$(63) = -C_{20} + C_{21} + 0{\cdot}12C_{50}$

$(64) = -C_{19} + C_{20} - 0{\cdot}12C_{50}$

$(65) = -C_{19} + 2{\cdot}22C_{44} - 2{\cdot}22C_{50}$

$(66) = +C_{19} - C_{20} - 4{\cdot}72C_{44} + 2{\cdot}22C_{50}$

$(67) = +C_{20} - C_{22} + 2{\cdot}50C_{44} + 1{\cdot}52C_{45} + 1{\cdot}52C_{46} + 1{\cdot}52C_{50}$

$(68) = -C_{23} - 7{\cdot}75C_{45} - 7{\cdot}75C_{46} - 1{\cdot}52C_{50}$

$(69) = +C_{22} + C_{23} + 6{\cdot}23C_{45} + 6{\cdot}23C_{46}$

$(70) = -C_{24} - C_{25} + 1{\cdot}39C_{46} + 1{\cdot}39C_{50}$

$(71) = -C_{22} + C_{24} + 8{\cdot}51C_{45}$

$(72) = +C_{25} - 10{\cdot}44C_{45} - 3{\cdot}32C_{46} - 1{\cdot}39C_{50}$

$(73) = -C_{20} + C_{22} + 1{\cdot}58C_{44} + 1{\cdot}93C_{45} + 1{\cdot}93C_{46} - 1{\cdot}58C_{50}$

$(74) = +C_{20} - C_{21} - 5{\cdot}52C_{44} + 1{\cdot}58C_{50}$

$(75) = +C_{21} + 3{\cdot}94C_{44}$

$(76) = +C_{23} - 0{\cdot}43C_{50}$

$(77) = -C_{25} + 0{\cdot}43C_{50}$

$(78) = +C_{25} - C_{26} + 1{\cdot}26C_{50}$

$(79) = -C_{23} + C_{26} - 1{\cdot}26C_{50}$

$(80) = -C_{22} - C_{23} + 4{\cdot}46C_{45} + 4{\cdot}46C_{46}$

$(81) = +C_{23} - C_{26} - 10{\cdot}04C_{45} - 4{\cdot}42C_{46} + 0{\cdot}04C_{50}$

$(82) = +C_{22} - C_{24} + 5{\cdot}58C_{45}$

$(83) = +C_{24} + C_{26} - C_{27} - C_{28} - 0{\cdot}04C_{46} + 1{\cdot}07C_{47} + 1{\cdot}03C_{50}$

$(84) = +C_{28} - 3{\cdot}53C_{47}$

$(85) = +C_{27} + 2{\cdot}46C_{47} - 1{\cdot}07C_{50}$

$(86) = -C_{28} - C_{29} + 1{\cdot}83C_{47} + 1{\cdot}83C_{50}$

$(87) = -C_{27} + C_{29} - 2{\cdot}73C_{47} - 1{\cdot}83C_{50}$

$(88) = -C_{24} - C_{26} + C_{27} + C_{28} + 3{\cdot}70C_{46} + 0{\cdot}90C_{47}$

$(89) = -C_{25} + C_{26} - 6{\cdot}46C_{46} - 2{\cdot}76C_{50}$

$(90) = +C_{24} + C_{25} + 2{\cdot}76C_{46} + 2{\cdot}76C_{50}$

$(91) = -C_{27} - 1{\cdot}76C_{50}$

$(92) = +C_{27} - C_{29} + 1{\cdot}76C_{50}$

$(93) = +C_{29} - C_{30} + 0{\cdot}93C_{48} + 0{\cdot}93C_{50}$

$(94) = +C_{30} - C_{32} - 11{\cdot}01C_{48} - 0{\cdot}93C_{50}$

$(95) = +C_{32} + 10{\cdot}08C_{48}$

$(96) = -C_{31} + 1{\cdot}60C_{48} + 1{\cdot}60C_{50}$

$(97) = -C_{30} + C_{31} - 2{\cdot}41C_{48} - 1{\cdot}60C_{50}$

$(98) = -C_{29} + C_{30} + 1{\cdot}72C_{47} + 0{\cdot}81C_{48} - 0{\cdot}59C_{50}$

(*c*) *Figure adjustment*—Continued.

Corrected equations—Completed.

$(99) = -C_{28} - 2{\cdot}31C_{47}$

$(100) = +C_{28} + C_{29} + 0{\cdot}59C_{47} + 0{\cdot}59C_{50}$

$(101) = -C_{36} + 11{\cdot}84C_{49}$

$(102) = -C_{34} + C_{36} - 13{\cdot}50C_{49} + 1{\cdot}66C_{50}$

$(103) = -C_{33} + C_{34} + 5{\cdot}26C_{48} + 1{\cdot}66C_{49} - 1{\cdot}66C_{50}$

$(104) = -C_{31} + C_{33} - 6{\cdot}15C_{48} - 0{\cdot}89C_{50}$

$(105) = +C_{31} + 0{\cdot}89C_{48} + 0{\cdot}89C_{50}$

$(106) = -C_{30} + C_{32} - 2{\cdot}11C_{50}$

$(107) = +C_{30} - C_{31} + 2{\cdot}11C_{50}$

$(108) = +C_{31} - C_{33} - 0{\cdot}93C_{50}$

$(109) = -C_{32} + C_{33} + 0{\cdot}93C_{50}$

$(110) = -C_{32} + 4{\cdot}12C_{48}$

$(111) = +C_{32} - C_{33} - 6{\cdot}27C_{48} - 2{\cdot}15C_{50}$

$(112) = +C_{33} - C_{34} + 2{\cdot}15C_{48} + 0{\cdot}70C_{49} + 2{\cdot}15C_{50}$

$(113) = +C_{34} - C_{35} - 3{\cdot}60C_{49} + 2{\cdot}90C_{50}$

$(114) = +C_{35} + 2{\cdot}90C_{49} - 2{\cdot}90C_{50}$

$(115) = +C_{36} - C_{37} + 0{\cdot}86C_{50}$

$(116) = -C_{35} + C_{37} - 0{\cdot}86C_{50}$

$(117) = -C_{34} + C_{35} - 1{\cdot}39C_{50}$

$(118) = +C_{34} - C_{36} + 1{\cdot}39C_{50}$

$(119) = -C_{36} + C_{37} - 5{\cdot}23C_{49} + 0{\cdot}70C_{50}$

$(120) = +C_{36} + 4{\cdot}53C_{49}$

$(121) = -C_{35} + 1{\cdot}56C_{49} - 1{\cdot}56C_{50}$

$(122) = +C_{35} - C_{37} - 4{\cdot}03C_{49} + 1{\cdot}56C_{50}$

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}
0=+0·58	+4		−2																				
+1·29		+4	+2																				
+0·46			+6	−2	−2																		
+0·28				+6	+2	−2																	
−2·28					+6	+2		−2															
−1·04						+6	−2																
−1·77							+6	+2	−2														
+1·00								+6	−2														
−1·14									+6	−2	+2												
+2·35										+6	+2	−2					−2						
+0·98											+6	−2											
−0·41												+6	−2	−2									
−1·15													+6			−2	−2						
−1·02														+6	−2								
+5·08															+6	−2							
+1·72																+6		−2					
−0·17																	+6						
−0·66																		+6	−2		−2		
+1·19																			+6	−2			
+0·51																				+6	−2	−2	
−1·98																					+6		
−0·18																						+6	+2
+1·12																							+6

(*c*) *Figure adjustment*—Continued.

Normal equations—Continued.

	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{39}	C_{40}
+ 0·58															+ 4·59		
+ 1·29															− 1·84		
+ 0·46															− 8·72	+ 2·63	
+ 0·28															+ 1·98	− 7·89	+18·40
− 2·28	...	...	...	...	...	...	..	..	. .	...	..	...	...	...	+ 1·98	+ 0·49	− 1·98
− 1·04																+ 6·28	+11·96
− 1·77																− 0·47	−29·40
+ 1·00																− 0·81	−19·10
− 1·14																	+8·86
− 0·18	−2																
+ 1·12			−2														
o = + 0·16	+6	+2	+2	−2	−2												
+ 0·78	...	+6	−2	...	...	...	...	...	...	...	...	...	...	...	....	....	....
− 0·54			+6	−2	−2												
+ 1·76				+6	+2	−2											
− 0·54					+6	+2											
− 1·16						+6	−2										
+ 0·34	...	...	...	...	...	...	+6	−2	−2		...	...	...	. .	....	....	....
+ 0·65								+6		−2							
+ 0·86									+6	−2							
− 3·08										+6	−2						
+ 0·50											+6	−2	−2				
− 2·58	...	...	...	...	...	...	..	...	...	...	...	+6		−2	....	....	....
+ 1·19													+6	−2			
− 1·95														+4			
+ 2·6															+57·262	+ 0·473	
− 2·7																+51·696	− 30·94
−11·2	...	...	...	...	...	...	...	...	..	...	...	...	..	...	....	....	+1 109·75

Normal equations—Continued.

	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}	C_{47}	C_{48}	C_{49}	C_{50}
+ 0·58										+ 4·16
+ 1·29										− 1·55
+ 0·46										− 5·66
+ 0·28										+ 0·63
− 2·28	....	....	....	....	....	....	....	....	....	+ 10·63
− 1·04										+ 4·32
− 1·77	+ 3·90									− 0·19
+ 1·00	+ 3·90									− 8·12
− 1·14	− 4·85	− 0·40								+ 4·13
+ 2·35	+ 7·23	− 5·17	− 4·18	....	....	....	....	....	....	+ 1·43
+ 0·98	+14·46	+ 5·98	− 4·18							+ 6·14
− 0·41	− 5·77	− 8·64	+10·85							− 4·48
− 1·15		+15·67	− 2·48							+ 0·71
− 1·02		+ 3·15	−14·11							+ 3·15
+ 5·08	....	....	+ 7·97	....	....	....	....	....	....	− 1·65
+ 1·72		− 3·61	− 1·47	+2·58						+ 1·00
− 0·17	+ 1·46	− 0·33	+ 0·62							+ 0·15
− 0·66			+ 0·91	−5·05						− 0·78
+ 1·19				+0·32						+ 0·17
+ 0·51	...	....	....	+0·12	− 0·41	−0·41	....	....	....	+ 2·22
− 1·98				+4·56						− 1·17
− 0·18				−0·92	− 0·75	+2·18				− 3·10

(c) *Figure adjustment*—Continued.

Normal equations—Completed.

	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}	C_{47}	C_{48}	C_{49}	C_{50}
+ 1.12					− 0.52	+5.10				+ 2.39
+ c.16					+ 2.93	−2.37	+0.17			+ 2.40
+ 0.78	....	....	....	....	−10.44	+4.51	....	...	....	+ 3.57
− 0.54					+10.04	−5.78	+0.17			− 4.29
+ 1.76						+3.74	+5.02			+ 3.25
− 0.54						+3.74	−2.63			− 2.27
− 1.16							−5.69	+ 0.12		− 3.31
+ 0.34	....	....	....	....	....	....	+1.72	− 8.72	....	+ 3.37
+ 0.65								+ 3.03		− 4.46
+ 0.86								+10.70		− 4.26
− 3.08								− 2.99	− 0.96	+ 6.93
+ 0.50								+ 3.11	+10.86	+ 0.21
− 2.58	....	....	....	....	....	....	...	....	+ 0.91	− 3.21
+ 1.19									−15.58	+ 0.43
− 1.95									− 1.20	− 2.58
+ 2.6										+ 12.322
− 2.7										+ 15.043
−11.2	− 2.50	....	....	....	....	....	....	....	....	+ 34.76
0=+ 2.5	+111.59	− 6.23	− 3.09							+ 2.69
− 4.4		+553.63	−114.86							+108.05
+ 7.0			+202.31	+ 5.82						−107.07
− 3.9				+137.91	+ 6.85	+ 6.85				− 41.42
+ 0.4	....	....	....	....	+438.15	+203.84	....	....	....	+ 25.15
+ 3.7						+220.33	+ 3.29			+ 42.82
− 2.4							+39.912	+ 1.39		+ 6.15
−11.5								+359.91	+ 10.24	+ 32.68
+ 2.2									+413.60	− 54.89
− 0.7	....	....	....	....	....	....	....	....	....	+265.947

Resulting values of correlates.

$C_{1}=-0.057$	$C_{14}=-0.420$	$C_{27}=-0.489$	$C_{40}=+0.026\ 98$
$C_{2}=-0.354$	$C_{15}=-1.246$	$C_{28}=+0.227$	$C_{41}=+0.028\ 9$
$C_{3}=-0.009$	$C_{16}=-0.873$	$C_{29}=+0.119$	$C_{42}=+0.007\ 13$
$C_{4}=-0.202$	$C_{17}=-0.211$	$C_{30}=+0.099$	$C_{43}=-0.029\ 2$
$C_{5}=+0.482$	$C_{18}=-0.172$	$C_{31}=+0.187$	$C_{44}=+0.026\ 5$
$C_{6}=+0.053$	$C_{19}=-0.273$	$C_{32}=+0.111$	$C_{45}=+0.005\ 36$
$C_{7}=+0.555$	$C_{20}=-0.050$	$C_{33}=+0.890$	$C_{46}=-0.011\ 7$
$C_{8}=-0.037$	$C_{21}=+0.231$	$C_{34}=+0.704$	$C_{47}=+0.153\ 5$
$C_{9}=+0.343$	$C_{22}=+0.123$	$C_{35}=+1.055$	$C_{48}=+0.032\ 6$
$C_{10}=-0.395$	$C_{23}=-0.279$	$C_{36}=+0.417$	$C_{49}=-0.008\ 89$
$C_{11}=-0.334$	$C_{24}=+0.060$	$C_{37}=+1.205$	$C_{50}=-0.024\ 2$
$C_{12}=-0.346$	$C_{25}=-0.189$	$C_{38}=-0.058\ 4$	
$C_{13}=-0.313$	$C_{26}=-0.215$	$C_{39}=+0.039\ 0$	

Resulting corrections to angular directions.

″	″	″	″
(1)=−0·031	(32)=+0·276	(63)=+0·278	(94)=−0·348
(2)=+0·588	(33)=+0·121	(64)=+0·226	(95)=+0·440
(3)=−0·090	(34)=+0·297	(65)=+0·386	(96)=−0·174
(4)=−0·321	(35)=−0·730	(66)=−0·402	(97)=+0·048
(5)=−0·515	(36)=+0·036	(67)=−0·154	(98)=+0·284
(6)=+0·255	(37)=+0·248	(68)=+0·365	(99)=−0·582
(7)=+0·143	(38)=+0·140	(69)=−0·196	(100)=+0·423
(8)=+0·318	(39)=−0·253	(70)=+0·079	(101)=−0·522
(9)=−0·201	(40)=−0·020	(71)=−0·017	(102)=−0·207
(10)=+0·202	(41)=−0·114	(72)=−0·172	(103)=+0·010
(11)=−0·178	(42)=+0·055	(73)=+0·240	(104)=+0·525
(12)=−0·201	(43)=+0·056	(74)=−0·465	(105)=+0·194
(13)=+0·408	(44)=+0·826	(75)=+0·335	(106)=+0·063
(14)=−0·527	(45)=−0·385	(76)=−0·269	(107)=−0·139
(15)=+0·297	(46)=−0·552	(77)=+0·179	(108)=−0·680
(16)=+0·273	(47)=+0·279	(78)=−0·004	(109)=+0·756
(17)=−0·391	(48)=−0·003	(79)=+0·094	(110)=+0·023
(18)=−0·437	(49)=+0·634	(80)=+0·128	(111)=−0·931
(19)=+0·555	(50)=−0·649	(81)=−0·067	(112)=+0·198
(20)=−0·006	(51)=−0·086	(82)=+0·093	(113)=−0·389
(21)=−0·334	(52)=−0·174	(83)=+0·246	(114)=+1·099
(22)=+0·044	(53)=+1·253	(84)=−0·315	(115)=−0·809
(23)=+0·226	(54)=−0·830	(85)=−0·085	(116)=+0·171
(24)=−0·470	(55)=−0·423	(86)=−0·109	(117)=+0·385
(25)=+0·540	(56)=−0·176	(87)=+0·233	(118)=+0·253
(26)=−0·324	(57)=+0·310	(88)=−0·012	(119)=+0·817
(27)=−0·179	(58)=+0·729	(89)=+0·117	(120)=+0·377
(28)=+0·273	(59)=+0·463	(90)=−0·228	(121)=−1·031
(29)=+0·594	(60)=−1·325	(91)=+0·532	(122)=−0·152
(30)=−0·225	(61)=−0·090	(92)=−0·651	
(31)=−0·139	(62)=−0·414	(93)=+0·027	

(*d*) *Adjusted triangles, Ohio.*

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
1	Davis.	50	14	45·62	−0·52	45·10	0·52	4·378 842 6	23 924·49
	Piney	66	33	51·22	−0·09	51·13	0·51	4·455 641 2	28 552·31
	Pigeon	63	11	25·29	+0·03	25·32	0·52	4·443 645 1	27 774·43
				02·13			1·55		
2	Gebhardt	34	57	29·07	−0·38	28·69	0·35	4·378 842 6	23 924·49
	Piney	117	16	06·18	−0·32	05·86	0·35	4·569 546 7	37 114·76
	Pigeon	27	46	27·09	−0·59	26·50	0·35	4·289 078 8	19 457·13
				02·34			1·05		

(*d*) *Adjusted triangles*, *Ohio*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
3	Gebhardt	85	02	10.85	−0.40	10.45	0.36	4.443 645 1	27 774.43
	Piney	50	42	14.96	−0.23	14.73	0.35	4.333 953 1	21 575.11
	Davis	44	15	35.71	+0.17	35.88	0.35	4.289 078 8	19 457.13
				01.52			1.06		
4	Gebhardt	50	04	41.78	−0.02	41.76	0.52	4.455 641 2	28 552.31
	Pigeon	35	24	58.20	+0.62	58.82	0.52	4.333 953 1	21 575.11
	Davis	94	30	21.33	−0.35	20.98	0.52	4.569 546 7	37 114.76
				01.31			1.56		
5	Wray	48	57	10.88	−0.67	10.21	0.36	4.333 953 1	21 575.11
	Gebhardt	88	01	08.22	+0.50	08.72	0.35	4.456 225 3	28 590.74
	Davis	43	01	42.25	−0.11	42.14	0.36	4.290 497 9	19 520.81
				01.35			1.07		
6	Oakland	29	22	48.53	−0.70	47.83	0.49	4.290 497 9	19 520.81
	Wray	100	32	59.95	−0.71	59.24	0.50	4.592 369 3	39 117.34
	Gebhardt	50	04	14.53	−0.11	14.42	0.50	4.484 475 1	30 512.31
				03.01			1.49		
7	Oakland	60	21	13.53	+0.31	13.84	0.58	4.456 225 3	28 590.74
	Wray	51	35	49.07	−0.04	49.03	0.58	4.411 284 8	25 780.11
	Davis	68	02	58.10	+0.77	58.87	0.58	4.484 475 2	30 512.32
				00.70			1.74		
8	Oakland	30	58	25.00	+1.01	26.01	0.44	4.333 953 1	21 575.11
	Gebhardt	37	56	53.69	+0.61	54.30	0.44	4.411 284 7	25 780.11
	Davis	111	04	40.35	+0.66	41.01	0.44	4.592 369 3	39 117.34
				59.04			1.32		
9	Fradd	14	50	33.64	+0.15	33.79	0.05	4.290 497 9	19 520.81
	Wray	159	11	36.04	+0.28	36.32	0.04	4.432 466 5	27 068.64
	Gebhardt	5	57	49.21	+0.82	50.03	0.05	3.898 597 9	7 917.68
				58.89			0.14		
10	Fradd	106	59	13.41	+0.60	14.01	0.17	4.484 475 1	30 512.31
	Wray	58	38	36.09	+0.99	37.08	0.17	4.435 279 9	27 244.57
	Oakland	14	22	09.25	+0.18	09.43	0.18	3.898 598 0	7 917.68
				58.75			0.52		
11	Fradd	92	08	39.77	+0.45	40.22	0.62	4.592 369 3	39 117.34
	Gebhardt	44	06	25.32	−0.94	24.38	0.63	4.435 280 0	27 244.57
	Oakland	43	44	57.78	−0.51	57.27	0.62	4.432 466 6	27 068.65
				02.87			1.87		

(*d*) *Adjusted triangles, Ohio*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
12	Gould	51	03	09 ·93	—0 ·11	09 ·82	0 ·57	4 ·435 279 9	27 244 ·57
	Fradd	83	32	13 ·71	—0 ·50	13 ·21	0 ·58	4 ·541 686 0	34 808 ·56
	Oakland	45	24	38 ·31	+0 ·38	38 ·69	0 ·57	4 ·397 030 0	24 947 ·67
				01 ·95			1 ·72		
13	Buena Vista	49	36	51 ·28	—1 ·03	50 ·25	0 ·55	4 ·397 030 0	24 947 ·67
	Gould	73	47	40 ·06	—0 ·50	39 ·56	0 ·56	4 ·497 640 4	31 451 ·43
	Fradd	56	35	32 ·67	—0 ·82	31 ·85	0 ·55	4 ·436 816 7	27 341 ·14
				04 ·01			1 ·66		
14	Buena Vista	109	29	09 ·86	—0 ·26	09 ·60	0 ·31	4 ·541 686 0	34 808 ·56
	Gould	22	44	30 ·13	—0 ·39	29 ·74	0 ·31	4 ·154 534 6	14 273 ·63
	Oakland	47	46	21 ·92	—0 ·33	21 ·59	0 ·31	4 ·436 816 8	27 341 ·15
				01 ·91			0 ·93		
15	Buena Vista	59	52	18 ·58	+0 ·77	19 ·35	0 ·33	4 ·435 279 9	27 244 ·57
	Fradd	26	56	41 ·04	+0 ·32	41 ·36	0 ·33	4 ·154 534 7	14 273 ·64
	Oakland	93	10	60 ·23	+0 ·05	60 ·28	0 ·33	4 ·497 640 4	31 451 ·43
				59 ·85			0 ·99		
16	Howland	63	40	26 ·41	0 ·00	26 ·41	0 ·32	4 ·436 816 7	27 341 ·14
	Gould	89	39	34 ·01	+0 ·23	34 ·24	0 ·31	4 ·484 363 1	30 504 ·44
	Buena Vista	26	39	60 ·12	+0 ·18	60 ·30	0 ·32	4 ·136 422 8	13 690 ·61
				00 ·54			0 ·95		
17	Scioto	12	30	50 ·65	—0 ·28	50 ·37	0 ·20	4 ·397 030 0	24 947 ·67
	Fradd	11	42	23 ·55	+0 ·09	23 ·64	0 ·21	4 ·368 495 9	23 361 ·24
	Gould	155	46	46 ·24	+0 ·36	46 ·60	0 ·20	4 ·674 264 0	47 235 ·01
				00 ·44			0 ·61		
18	Scioto	34	31	50 ·70	+0 ·64	51 ·34	0 ·17	4 ·136 422 8	13 690 ·61
	Gould	40	45	59 ·69	—0 ·10	59 ·59	0 ·18	4 ·197 852 9	15 770 ·77
	Howland	104	42	08 ·99	+0 ·61	09 ·60	0 ·18	4 ·368 495 9	23 361 ·24
				59 ·38			0 ·53		
19	Cave	87	29	45 ·35	+0 ·41	45 ·76	0 ·29	4 ·484 363 1	30 504 ·44
	Howland	69	23	10 ·97	+0 ·77	11 ·74	0 ·29	4 ·456 043 0	28 578 ·74
	Buena Vista	23	07	03 ·53	—0 ·16	03 ·37	0 ·29	4 ·078 748 7	11 988 ·06
				59 ·85			0 ·87		
20	Round Top	44	15	56 ·99	—0 ·27	56 ·72	0 ·25	4 ·197 852 9	15 770 ·77
	Scioto	59	14	33 ·78	—1 ·28	32 ·50	0 ·25	4 ·288 169 6	19 416 ·44
	Howland	76	29	31 ·71	—0 ·17	31 ·54	0 ·26	4 ·341 822 8	21 969 ·63
				02 ·48			0 ·76		

(*d*) *Adjusted triangles, Ohio*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
21	Round Top	37	50	52·48	−1·79	50·69	0·14	4·078 748 7	11 988·06
	Howland	45	44	41·92	−1·21	40·71	0·14	4·145 947 8	13 994·19
	Cave	96	24	31·10	−2·08	29·02	0·14	4·288 169 7	19 416·44
				05·50			0·42		
22	Twin Creek	77	37	10·17	−0·32	09·85	0·21	4·341 822 8	21 969·63
	Scioto	32	14	02·00	+0·56	02·56	0·21	4·079 076 9	11 997·12
	Round Top	70	08	47·80	+0·42	48·22	0·21	4·325 430 7	21 155·86
				59·97			0·63		
23	Peach Mount	43	29	17·56	−0·79	16·77	0·40	4·325 430 7	21 155·86
	Scioto	47	09	02·61	−0·09	02·52	0·41	4·352 904 4	22 537·43
	Twin Creek	89	21	42·23	−0·31	41·92	0·40	4·487 688 4	30 738·91
				02·40			1·21		
24	Cherry Ridge	53	11	43·91	−0·71	43·20	0·35	4·352 904 4	22 537·43
	Peach Mount	40	05	57·46	+0·25	57·71	0·35	4·258 407 2	18 130·39
	Twin Creek	86	42	20·18	−0·05	20·13	0·34	4·448 726 3	28 101·29
				01·55			1·04		
25	Cherry Ridge	20	10	13·41	+0·80	14·21	0·18	4·079 076 9	11 997·12
	Twin Creek	106	18	47·42	+0·69	48·11	0·17	4·387 198 4	24 389·25
	Round Top	45	30	57·72	+0·49	58·21	0·18	4·258 406 9	18 130·38
				58·55			0·53		
26	Cave Hill	78	31	39·56	+0·45	40·01	0·40	4·448 726 3	28 101·29
	Peach Mount	54	05	08·82	+0·52	09·34	0·41	4·365 920 5	23 223·12
	Cherry Ridge	47	23	11·46	+0·41	11·87	0·41	4·324 332 1	21 102·41
				59·84			1·22		
27	Ash Ridge	25	17	14·24	−0·20	14·04	0·19	4·324 332 1	21 102·41
	Peach Mount	18	40	30·71	−0·56	30·15	0·20	4·199 166 6	15 818·55
	Cave Hill	136	02	16·76	−0·36	16·40	0·20	4·535 220 1	34 294·16
				01·71			0·59		
28	Ash Ridge	45	56	50·07	−0·04	50·03	0·78	4·448 726 3	28 101·29
	Peach Mount	72	45	39·53	−0·04	39·49	0·78	4·572 218 1	37 343·77
	Cherry Ridge	61	17	32·56	+0·26	32·82	0·78	4·535 220 1	34 294·16
				02·16			2·34		
29	Ash Ridge	20	39	35·83	+0·16	35·99	0·17	4·365 920 5	23 223·12
	Cave Hill	145	26	03·68	−0·09	03·59	0·18	4·572 218 2	37 343·78
	Cherry Ridge	13	54	21·10	−0·15	20·95	0·18	4·199 166 6	15 818·55
				00·61			0·53		

(*d*) *Adjusted triangles*, *Ohio*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
30	Minerva	29	40	55 ·14	+0 ·13	55 ·27	0 ·37	4 ·199 166 6	15 818 ·55
	Ash Ridge	91	12	51 ·00	+0 ·31	51 ·31	0 ·36	4 ·504 302 1	31 937 ·59
	Cave Hill	59	06	14 ·42	+0 ·10	14 ·52	0 ·37	4 ·437 937 5	27 411 ·80
				00 ·56			1 ·10		
31	Minerva	66	57	21 ·54	−0 ·21	21 ·33	0 ·82	4 ·572 218 1	37 343 ·77
	Ash Ridge	70	33	15 ·17	+0 ·15	15 ·32	0 ·81	4 ·582 826 0	38 267 ·14
	Cherry Ridge	42	29	25 ·90	−0 ·10	25 ·80	0 ·82	4 ·437 937 6	27 411 ·80
				02 ·61			2 ·45		
32	Minerva	37	16	26 ·40	−0 ·35	26 ·05	0 ·63	4 ·365 920 5	23 223 ·12
	Cave Hill	86	19	49 ·26	−0 ·18	49 ·08	0 ·62	4 ·582 826 2	38 267 ·16
	Cherry Ridge	56	23	47 ·00	−0 ·25	46 ·75	0 ·63	4 ·504 302 2	31 937 ·60
				02 ·66			1 ·88		
33	Tate	50	08	36 ·41	−1 ·18	35 ·23	0 ·68	4 ·437 937 5	27 411 ·80
	Ash Ridge	63	03	06 ·66	−0 ·33	06 ·33	0 ·68	4 ·502 856 6	31 831 ·46
	Minerva	66	48	20 ·73	−0 ·25	20 ·48	0 ·68	4 ·516 174 1	32 822 ·68
				03 ·80			2 ·04		
34	Flaugher	42	24	20 ·07	−0 ·87	19 ·20	0 ·66	4 ·516 174 1	32 822 ·68
	Tate	106	48	21 ·37	−0 ·50	20 ·87	0 ·67	4 ·668 320 8	46 593 ·01
	Ash Ridge	30	47	21 ·69	+0 ·23	21 ·92	0 ·66	4 ·396 446 1	24 914 ·15
				03 ·13			1 ·99		
35	Flaugher	74	24	32 ·79	+0 ·14	32 ·93	0 ·56	4 ·502 856 6	31 831 ·46
	Tate	56	39	44 ·96	+0 ·68	45 ·64	0 ·56	4 ·441 057 5	27 609 ·43
	Minerva	48	55	42 ·77	+0 ·34	43 ·11	0 ·56	4 ·396 446 1	24 914 ·15
				00 ·52			1 ·68		
36	Flaugher	32	00	12 ·72	+1 ·00	13 ·72	0 ·58	4 ·437 937 5	27 411 ·80
	Ash Ridge	32	15	44 ·97	−0 ·56	44 ·41	0 ·57	4 ·441 057 4	27 609 ·43
	Minerva	115	44	03 ·50	+0 ·10	03 ·60	0 ·58	4 ·668 320 7	46 593 ·00
				01 ·19			1 ·73		
37	Stevens	44	54	59 ·19	−0 ·20	58 ·99	0 ·63	4 ·396 446 1	24 914 ·15
	Tate	66	11	15 ·10	−0 ·38	14 ·72	0 ·63	4 ·508 956 5	32 281 ·71
	Flaugher	68	53	47 ·95	+0 ·24	48 ·19	0 ·64	4 ·517 447 1	32 919 ·04
				02 ·24			1 ·90		
38	Dry Ridge	67	08	27 ·09	−0 ·33	26 ·76	0 ·66	4 ·508 956 5	32 281 ·71
	Stevens	60	13	25 ·37	−0 ·54	24 ·83	0 ·66	4 ·482 983 5	30 407 ·69
	Flaugher	52	38	10 ·17	+0 ·22	10 ·39	0 ·66	4 ·444 735 7	27 844 ·26
				02 ·63			1 ·98		

(*d*) *Adjusted triangles, Ohio*—Completed.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
39	Tanner	27	04	34·43	−0·96	33·47	0·26	4·517 447 1	32 919·04
	Tate	11	47	36·08	+0·79	36·87	0·26	4·169 722 3	14 781·63
	Stevens	141	07	51·13	−0·69	50·44	0·26	4·656 919 6	45 385·76
				01·64			0·78		
40	Tanner	44	26	50·32	+1·13	51·45	0·32	4·444 735 7	27 844·26
	Stevens	113	43	44·31	+1·44	45·75	0·32	4·561 116 9	36 401·30
	Dry Ridge	21	49	23·25	+0·51	23·76	0·32	4·169 722 3	14 781·63
				57·88			0·96		
41	Stow	56	43	55·69	−0·13	55·56	1·00	4·561 116 9	36 401·30
	Tanner	71	25	33·05	−0·59	32·46	1·00	4·615 619 4	41 268·57
	Dry Ridge	51	50	34·76	+0·22	34·98	1·00	4·534 450 8	34 233·46
				03·50			3·00		
42	Reizin	53	27	20·56	+0·88	21·44	0·73	4·534 450 8	34 233·46
	Tanner	36	00	51·10	+1·49	52·59	0·73	4·398 889 4	25 054·71
	Stow	90	31	47·94	+0·21	48·15	0·72	4·629 502 0	42 609·07
				59·60			2·18		
43	Culbertson	71	44	14·84	+0·82	15·66	0·33	4·398 889 4	25 054·71
	Reizin	40	29	33·13	+0·15	33·28	0·34	4·233 812 1	17 132·16
	Stow	67	46	11·09	+0·98	12·07	0·34	4·387 791 6	24 422·58
				59·06			1·01		
44	Culbertson	24	56	52·50	−0·44	52·06	0·35	4·615 619 4	41 268·57
	Stow	144	58	05·28	−1·06	04·22	0·34	4·749 462 7	56 164·60
	Dry Ridge	10	05	04·44	+0·31	04·75	0·34	4·233 812 0	17 132·15
				02·22			1·03		

(*e*) *Precision of the Ohio series of triangles.*

The probable error in length of any side of the series of triangles due to the angular measures is derived as usual by means of the formulæ—

$$m = \sqrt{\frac{2\,[vv]}{c}}\,,\quad u_{a_n} = \tfrac{2}{3}\,(\delta_{a_n})^{-2}\,\Sigma_{a_1}^{a_n}\,[\delta_A^2 + \delta_A\delta_B + \delta_B^2] \text{ and } e_{a_n} = 0{\cdot}674\,5 \text{ metre } \sqrt{u_{a_n}}$$

To this must be added the probable error due to the side of the base net.

From the solution of 50 normal equations involving 122 directions $m = \pm 0''{\cdot}93$.

The side Cherry Ridge to Peach Mount is selected as dividing the series of triangles into two nearly equal parts. $\delta_{a_n} = 15{\cdot}4$ in units of the sixth place of decimals of the logarithm of the side. Starting from the side Piney to Pigeon of the St. Albans Base Net, we have $\Sigma = 97{\cdot}7$ (12 triangles), $e_{a_n} = \pm 0{\cdot}330$ metre, $e_b = \pm 0{\cdot}141$ metre, and $e_1 = \pm 0{\cdot}359$ metre. Starting from the side Reizin to Culbertson of the Holton Base Net $\Sigma = 69{\cdot}8$ (11 triangles), $e_{a_n} = \pm 0{\cdot}278$ metre, $e_b = \pm 0{\cdot}095$ metre, and $e_2 = \pm 0{\cdot}294$

metre. The probable error in length of Cherry Ridge to Peach Mount as a side of the adjusted triangulation becomes $e = \frac{e_1 e_2}{\sqrt{e_1^2 + e_2^2}} = \pm 0{\cdot}227$ metre, or about $\frac{1}{134\,000}$ part of the length.

The effect on the arc is approximately (the distance being measured along the thirty-ninth parallel between the projections of the middle points of the terminal lines) as follows:

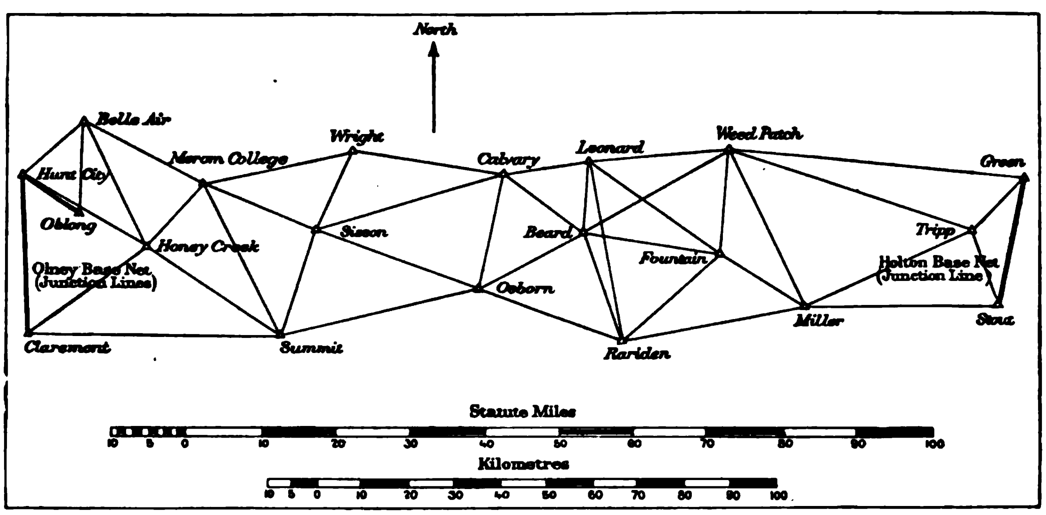
Terminal lines.	Distance.	Probable errors.		Average.	
	km.				*m.*
Piney to Pigeon to Cherry Ridge to Peach Mount	118	$\frac{1}{199\,000}$	$\frac{1}{124\,000}$	$\frac{1}{153\,000}$	±0·77
Cherry Ridge to Peach Mount to Reizin to Culbertson	151	$\frac{1}{124\,000}$	$\frac{1}{297\,000}$	$\frac{1}{175\,000}$	0·86
				Sum	±1·63

4. THE INDIANA SERIES OF TRIANGLES, 1879, 1884–85–86–87, 1889–90.

(a) *Introduction.*

This triangulation, following closely the parallel of 39°, traverses southern Indiana, but the western figure of this series lies almost wholly in Illinois. The following information was furnished by the observer: The ground is a slightly undulating plain, gradually sloping to the Wabash River at an elevation above sea level of considerably

No. 28.



less than 500 feet. A sharp geological fault along the line of the Wabash River marks a change which is quite apparent in the surface features. On the Indiana side, starting with the high bluff on which the village of Merom is situated, the country eastward is decidedly rolling, the ridges narrow, and the hills well marked. It gradually rises from an elevation of more than 500 feet at Merom to about 800 feet at the crest of the divid-

ing ridge between the White and Ohio rivers. Weed Patch, the most northern station in this series, is said to be the highest point in the State, being about 1 150 feet above sea level. The forests are extensive and the trees of great size; along the Wabash and in the White River country often rising to a height of 140 feet and over. The best land being in the bottoms, the hills and ridges are for the most part wooded, while the cultivation is largely confined to the lowlands.

It was through this section that our highest towers were needed, and even then considerable cutting had to be resorted to. All the observations were made on lights at night.

The total length of the series between the base-net lines is nearly 216 kilometres (or 135 statute miles); the number of stations is 15; the average length of a side is 32 kilometres (or 19·9 statute miles); the number of series of measures at a station (mean of telescope *D.* and *R.*) exceeds 34,* and the usual number of the positions of the circle is 17. Assistant G. A. Fairfield had charge of this work, and all observations excepting some at the stations forming parts of the two base-net figures.

(*b*) *Abstract of resulting horizontal directions at stations of the Indiana series of triangles, between Holton and Olney base nets.*

Oblong, Crawford County, Illinois. October and November, 1879. 35-centimetre theodolite, Pistor & Martins, No. 2. Telescope above ground 30·94 metres. G. Y. Wisner, observer, United States Lake Survey.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Claremont	0	00	00·00		+0·37		00·37
	Buffalo Mound	34	36	31·20		−0·38		30·82
	Hunt City	100	27	20·78		+0·02		20·80
	Casey	132	34	08·03				
5	Belle Air	160	10	26·65			+0·21	26·86
					Mean	0·00		

*The intention was to observe each direction 34 times, but owing to the presence of broken series their total number is much greater.

(*b*) *Abstract of resulting horizontal directions at stations of the Indiana series of triangles, between Holton and Olney base nets*—Continued.

Claremont, Richland County, Illinois. November, 1879. 35-centimetre theodolite, Pistor & Martins, No. 2. Telescope above ground 24·84 metres. G. Y. Wisner, observer, United States Lake Survey. July 26 to August 22, 1884. 30-centimetre theodolite, No. 107. Telescope above ground 24·84 metres. G. A. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Denver	0	00	00·00	±0·13	+0·65		00·65
	Onion Hill	17	49	15·39		−0·12		15·27
	Olney West Base	46	01	29·05		−0·41		28·64
	Newton	46	54	49·55	·21	−0·01		49·54
	Check Base	53	26	11·07		−0·21		10·86
	Buffalo Mound	66	48	58·15		−0·30		57·85
	Olney East Base	71	56	44·50		−0·23		44·27
	Hunt City	82	16	50·46	·16	+0·56		51·02
	Oblong	106	32	51·56		+0·07		51·63
1	Honey Creek	138	23	11·73	·20		−0·11	11·62
2	Summit	174	40	19·45	·13		−0·20	19·25
	Parkersburg	274	17	40·86				
					Mean	0·00		

Probable error of a single observation (*D.* and *R.*) in 1884, = ± 1″·03.

Hunt City, Jasper County, Illinois. October, 1879. 35-centimetre theodolite, Troughton & Simms, No. 3. Telescope above ground 23·32 metres. R. S. Woodward, observer, United States Lake Survey. September 5 to September 17, 1884. 30-centimetre theodolite, No. 107. Telescope above ground 23·32 metres. G. A. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and first figure adjustments.	Corrections from base-net and first and second figure adjustments.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
3	Belle Air	0	00	00·00	±0·16			+0·40	00·40
4	Honey Creek	74	41	37·75	0·20			+0·03	37·78
	Oblong	75	44	47·03		+0·12			47·15
	Claremont	131	01	27·19	0·27	−0·07			27·12
	Buffalo Mound	145	05	08·91		0·12			08·79
	Newton	173	22	02·19	0·19	+0·07			02·26
	Island Creek	232	34	09·67	0·23		−0·80		10·47
	Casey	313	18	25·33					
						Mean	+0·16		

Probable error of a single observation (*D.* and *R.*) = ± 1″·25, in 1884.

(*b*) *Abstract of resulting horizontal directions at stations of the Indiana series of triangles, between Holton and Olney base nets*—Continued.

Honey Creek, Crawford County, Illinois. October 14 to October 25, 1884. 30-centimetre theodolite, No. 107. Telescope above ground 23·32 metres. G. A. Fairfield, observer.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
9	Merom College	0	00	00·00	±0·16	−0·25	59·75
10	Summit	79	27	49·61	0·17	0·00	49·61
6	Claremont	191	16	59·91	0·15	+0·18	60·09
7	Hunt City	258	50	52·24	0·17	+0·14	52·38
8	Belle Air	291	55	09·40	0·23	−0·06	09·34

Probable error of a single observation (*D.* and *R.*) = ± 1″·04.

Belle Air, Clark County, Illinois. October, 1879. 35-centimetre theodolite, Troughton & Simms, No. 4. Telescope above ground 30·94 metres. J. H. Darling, observer, United States Lake Survey. October 3 to October 6, 1884. 30-centimetre theodolite, No. 107. Telescope above ground 30·94 meters. J. B. Boutelle. observer.

		°	′	″	″	″	″
14	Hunt City	0	00	00·00	±0·16	−0·12	59·88
	Casey	66	58	14·70			
	Martinsville	138	45	56·50			
11	Merom College	251	52	08·01	0·23	+0·45	08·46
12	Honey Creek	287	45	52·89	0·23	0·00	52·89
13	Oblong	315	27	52·39		−0·32	52·07

Probable error of a single observation (*D.* and *R.*) = ± 1″·28, in 1884.

Merom College, Sullivan County, Indiana. September 18 to September 23, 1885. 30-centimetre theodolite, No. 145. Telescope above ground 29·26 metres. G. A. Fairfield, observer.

		°	′	″	″	″	″
18	Honey Creek	0	00	00·00	±0·25	+0·31	00·31
19	Belle Air	76	01	27·12	0·22	−0·26	26·86
15	Wright	214	13	53·85	0·26	5	54·20
16	Sisson	248	15	06·68	0·25	0·32	06·36
17	Summit	290	12	61·80	0·22	−0·08	61·72

Probable error of a single observation (*D.* and *R.*) = ± 1″·39.

Sisson, Sullivan County, Indiana. October 16 to November 5, 1885. 30-centimetre theodolite, No. 145. Telescope above ground 23·32 metres. G. A. Fairfield, observer.

		°	′	″	″	″	″
30	Wright	0	00	00·00	±0·15	−0·16	59·84
31	Calvary	48	12	26·70	0·28	+0·19	26·89
32	Osborn	84	10	30·59	0·17	−0·08	30·51
28	Summit	172	27	26·65	0·17	−0·25	26·40
29	Merom College	265	15	31·20	0·22	+0·21	31·51

Probable error of a single observation (*D.* and *R.*) = ± 1″·22.

(*b*) *Abstract of resulting horizontal directions at stations of the Indiana series of triangles, between Holton and Olney base nets*—Continued.

Summit, Knox County, Indiana. November 5 to November 11, 1884. 30-centimetre theodolite, No. 107. August 11 to August 26, 1885. 30-centimetre theodolite, No. 145. Telescope above ground 24·84 metres. G. A. Fairfield, observer.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
23	Sisson	0	00	00·00	±0·19	+0·24	00·24
24	Osborn	58	27	44·67	0·22	−0·23	44·44
20	Claremont	252	07	01·69	0·23	−0·15	01·54
21	Honey Creek	284	00	46·01	0·15	−0·05	45·96
22	Merom College	314	45	58·95	0·14	+0·19	59·14

Probable error of a single observation (*D.* and *R.*) = ± 1″·20.

Wright, Greene County, Indiana. September 14 to September 21, 1886. 30-centimetre theodolite, No. 145. Telescope above ground 23·32 metres. G. A. Fairfield, observer.

		°	′	″	″	″	″
26	Sisson	0	00	00·00	±0·18	+0·11	00·11
27	Merom College	51	14	20·94	0·21	−0·12	20·82
25	Calvary	252	41	05·05	0·20	+0·01	05.06

Probable error of a single observation (*D.* and *R.*) = ± 1″·21.

Osborn, Martin County, Indiana. November 14 to December 2, 1886. 30-centimetre theodolite, No. 145. June 14 to June 20, 1887. 30-centimetre theodolite, No. 147. Telescope above ground 24·84 metres. G. A. Fairfield, observer.

		°	′	″	″	″	″
35	Calvary	0	00	00·00	±0·12	−0·22	$\overline{59·78}$
36	Beard	49	22	10·43	0·21	+0·53	10·96
37	Rariden	96	46	42·19	0·20	−0·21	41·98
33	Summit	244	07	23·58	0·22	−0·05	23·53
34	Sisson	277	22	45·82	0·18	−0·05	45·77
	Azimuth Mark	343	28	51·49	0·20		

Probable error of a single observation (*D.* and *R.*) = ± 1″·22.

Calvary, Greene County, Indiana. October 11 to October 30, 1886. 30-centimetre theodolite, No. 145. Telescope above ground 23·32 metres. G. A. Fairfield, observer.

		°	′	″	″	″	″
40	Osborn	0	00	00·00	±0·22	+0·01	00·01
41	Sisson	61	24	44·79	0·20	−0·02	44·77
42	Wright	85	53	23·99	0·18	+0·18	24·17
38	Leonard	247	24	45·99	0·25	−0·32	45·67
39	Beard	292	35	58·08	0·26	+0·15	58·23

Probable error of a single observation (*D.* and *R.*) = ± 1″·35.

(*b*) *Abstract of resulting horizontal directions at stations of the Indiana series of triangles, between Holton and Olney base nets*—Continued.

Beard, Lawrence County, Indiana. September 14 to September 25, 1887. 30-centimetre theodolite, No. 147. Telescope above ground 26·97 metres. G. A. Fairfield, observer.

	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
44	Calvary	0 00 00·00	±0·16	+0·13	00·13
45	Leonard	57 15 27·50	0·17	−0·07	27·43
46	Weed Patch	111 57 30·11	0·20	−0·03	30·08
47	Fountain	149 48 18·15	0·22	+0·13	18·28
48	Rariden	214 45 51·97	0·23	+0·20	52·17
43	Osborn	296 46 12·19	0·17	−0·36	11·83

Probable error of a single observation ($D.$ and $R.$) = ± 1″·16.

Rariden, Lawrence County, Indiana. July 14 to September 5, 1887. 30-centimetre theodolite, No. 147. Telescope above ground 23·32 metres. G. A. Fairfield, observer.

		° ′ ″	″	″	″
50	Beard	0 00 00·00	±0·13	+0·18	00·18
51	Leonard	8 38 02·96	0·12	−0·47	02·49
52	Fountain	67 27 44·85	0·17	+0·46	45·31
53	Miller	97 03 49·55	0·22	+0·11	49·66
49	Osborn	309 24 49·52	0·18	−0·28	49·24

Probable error of a single observation ($D.$ and $R.$) = ± 1″·04.

Leonard, Monroe County, Indiana. October 11 to October 19, 1887. 30-centimetre theodolite, No. 147. Telescope above ground 23·32 metres. G. A. Fairfield, observer.

		° ′ ″	″	″	″
58	Calvary	0 00 00·00	±0·18	+0·26	00·26
54	Weed Patch	178 38 14·12	0·16	−0·26	13·86
55	Fountain	221 04 24·51	0·20	−0·43	24·08
56	Rariden	268 35 05·92	0·24	+0·16	06·08
57	Beard	282 26 39·13	0·15	+0·27	39·40

Probable error of a single observation ($D.$ and $R.$) = ± 1″·12.

Fountain, Jackson County, Indiana. October 30 to November 13, 1887. 30-centimetre theodolite, No. 147. Telescope above ground 32·77 metres. G. A. Fairfield, observer.

		° ′ ″	″	″	″
59	Rariden	0 00 00·00	±0·16	−0·43	$\overline{59}$·57
60	Beard	47 34 42·06	0·22	+0·27	42·33
61	Leonard	73 39 37·18	0·18	+0·20	37·38
62	Weed Patch	140 02 35·25	0·19	+0·28	35·53
63	Miller	252 45 43·60	0·16	−0·31	43·29

Probable error of a single observation ($D.$ and $R.$) = ± 1″·14.

(*b*) *Abstract of resulting horizontal directions at stations of the Indiana series of triangles, between Holton and Olney base nets*—Continued.

Weed Patch, Brown County, Indiana. August 3 to September 6, 1889. 30-centimetre theodolite, No. 147. Telescope above ground 23·32 metres. G. A. Fairfield, observer.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
67	Fountain	0	00	00·00	±0·10	−0·10	59·90
68	Beard	49	41	20·54	0·21	−0·07	20·47
69	Leonard	71	30	53·17	0·19	+0·42	53·59
	Wray	192	57	49·37	0·21		
	Union	224	16	03·26	0·38		
	Monroe (Azimuth Mark)	267	50	26·64	0·24		
64	Green	268	47	46·61	0·28	+0·09	46·70
65	Tripp	282	48	07·44	0·19	−0·24	07·20
	Pinnacle	321	18	40·37	0·22		
66	Miller	328	47	02·66	0·20	−0·11	02·55

Probable error of a single observation (*D.* and *R.*) = ± 1″·24.

Miller, Jackson County, Indiana. October 2 to November 2, 1889. 30-centimetre theodolite, No. 147. Telescope above ground 24·84 metres. G. A. Fairfield, observer.

	Objects observed.	°	′	″	″	″	″
71	Fountain	0	00	00·00	±0·15	+0·49	00·49
72	Weed Patch	36	03	56·66	0·22	+0·01	56·67
	Monroe	56	13	05·97	0·25		
	Pinnacle	104	55	16·37	0·41		
73	Tripp	122	29	32·45	0·19	−0·28	32·17
74	Stout	147	51	57·29	0·26	+0·35	57·64
	Holman	170	59	21·61	0·25		
	Finley	209	25	19·73	0·24		
70	Rariden	316	50	20·05	0·31	−0·57	19·48

Probable error of a single observation (*D.* and *R.*) = ± 1″·32.

Tripp, Jennings County, Indiana. June 10 to June 26, 1890. 30-centimetre theodolite, No. 147. Telescope above ground 30·94 metres. G. A. Fairfield and J. B. Boutelle, observers.

	Objects observed.	°	′	″	″	″	″
78	Stout	0	00	00·00	±0·20	+0·33	00·33
75	Miller	82	25	52·05	0·25	−0·08	51·97
	Pinnacle	85	09	52·32	0·28		
76	Weed Patch	130	01	25·67	0·22	−0·77	24·90
	Monroe	135	05	36·42	0·21		
77	Green	246	03	20·14	0·16	+0·51	20·65

Probable error of a single observation (*D.* and *R.*) = ± 1″·34.)

(*b*) *Abstract of resulting horizontal directions at stations of the Indiana series of triangles, between Holton and Olney base nets*—Continued.

Stout, Jefferson County, Indiana. August 29 to September 13, 1890. 30-centimetre theodolite, No. 147. Telescope above ground 41·91 metres. J. B. Boutelle, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustments.	Final seconds in triangulation.
		°	′	″	″	″	″	″
80	Tripp	0	00	00·00	±0·13		−0·70	59·30
	Green	32	33	05·72	0·24	+0·14		05·86
	Correct	74	01	21·01	0·20	−0·17		20·84
	Mud Lick	111	17	21·59	0·22	+0·03		21·62
	Holman	224	28	07·36	0·32			
79	Miller	287	48	14·96	0·26		−0·21	14·75
					Mean	0·00		

Probable error of a single observation (*D.* and *R.*) = ± 1″·38.

Green, Jennings County, Indiana. July 11 to August 14, 1890. 30-centimetre theodolite, No. 147. Telescope above ground 46·79 metres. J. B. Boutelle, observer. November 19 to November 20, 1890. 30-centimetre theodolite, No. 118. Telescope above ground 46·79 metres. W. B. Fairfield, observer.

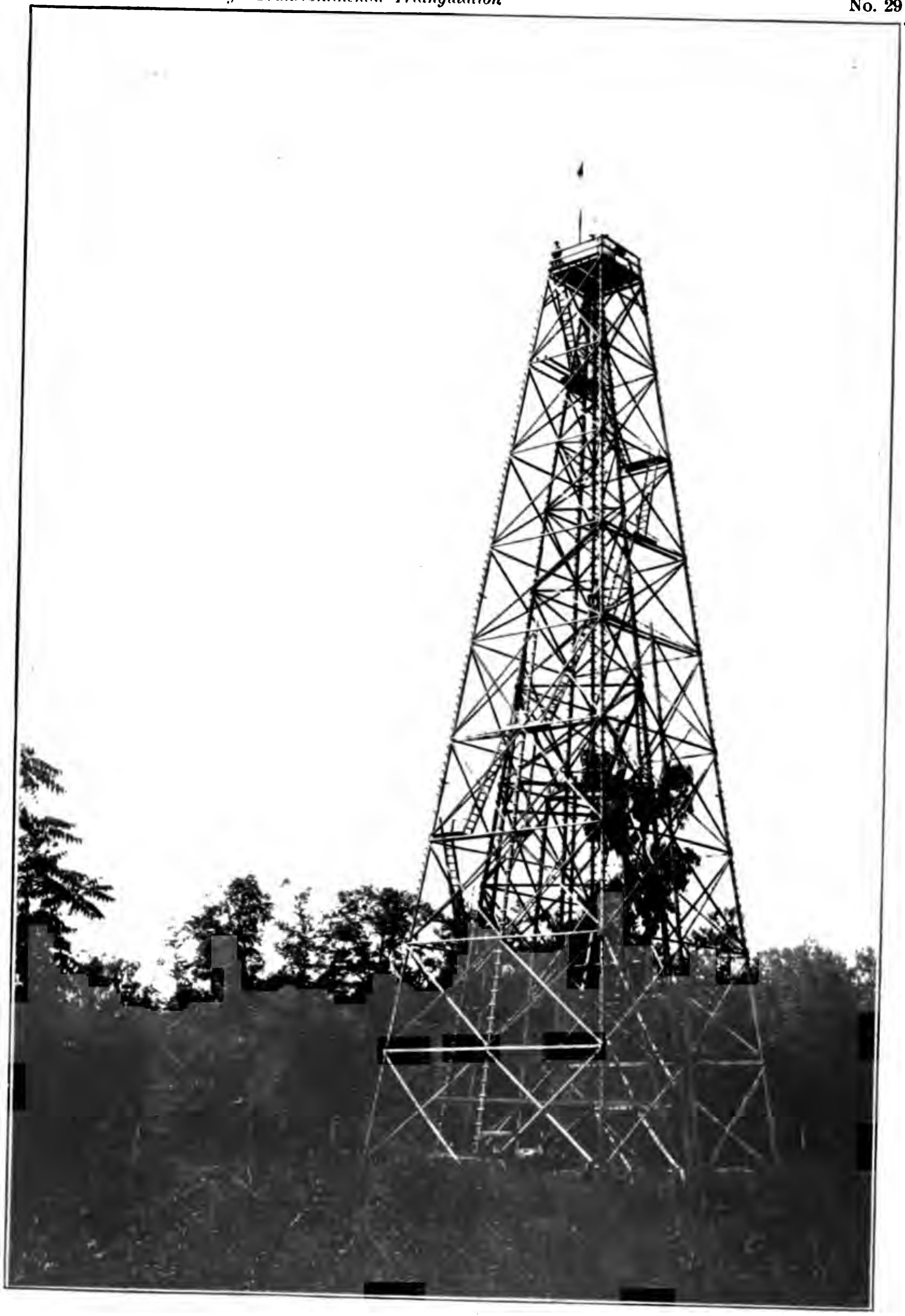
No. of direction.	Objects observed.	°	′	″	″	″	″	″
81	Tripp	0	00	00·00	±0·12		−0·94	59·06
82	Weed Patch	49	57	43·52	0·20		+1·31	44·83
	Glasgow	222	13	20·09	0·16	+0·15		20·24
	Holton North Base	235	33	52·93	0·22	+0·10		53·03
	Correct	250	01	28·54	0·20	−0·15		28·39
	Holton South Base	257	24	24·18	0·18	+0·41		24·59
	Stout	326	29	45·14	0·20	−0·51		44·63
					Mean	0·00		

Probable error of a single observation (*D.* and *R.*) = ± 1″·15.

(*c*) *Figure adjustment.*

Observation equations.

1 | $0 = -0.17 - (3) + (5) - (13) + (14)$
2 | $0 = +0.02 + (1) - (4) - (6) + (7)$
3 | $0 = +0.69 \quad (3) + (4) - (7) + (8) - (12) + (14)$
4 | $0 = -0.18 - (1) + (2) + (6) - (10) - (20) + (21)$
5 | $0 = +1.22 - (8) + (9) - (11) - (12) - (18) + (19)$
6 | $0 = -0.88 - (9) + (10) - (17) + (18) - (21) + (22)$
7 | $0 = -0.86 - (16) + (17) - (22) + (23) - (28) + (29)$
8 | $0 = +1.37 - (15) + (16) - (26) + (27) - (29) + (30)$
9 | $0 = +0.65 - (23) - (24) + (28) - (32) - (33) + (34)$
10 | $0 = -0.64 - (25) + (26) - (30) + (31) - (41) + (42)$
11 | $0 = +0.47 - (31) + (32) - (34) + (35) - (40) + (41)$
12 | $0 = -1.11 - (35) + (36) - (39) + (40) - (43) + (44)$



SCAFFOLDING AT STATION, GREENE, IND.

Elevation of instrument above ground, 46.3 meters or 152 feet.

(*c*) *Figure adjustment*—Continued.

Observation equations—Continued.

13 $0 = +0.83 - (36) + (37) + (43) - (48) - (49) + (50)$

14 $0 = -0.25 - (38) + (39) - (44) + (45) - (57) + (58)$

15 $0 = -1.05 - (47) + (48) - (50) + (52) - (59) + (60)$

16 $0 = -2.15 - (51) + (52) - (55) + (56) - (59) + (61)$

17 $0 = -1.06 - (45) + (46) - (54) + (57) - (68) + (69)$

18 $0 = -0.20 - (46) + (47) - (60) + (62) - (67) + (68)$

19 $0 = -0.43 - (54) + (55) - (61) + (62) - (67) + (69)$

20 $0 = -0.58 - (52) + (53) + (59) - (63) - (70) + (71)$

21 $0 = +1.06 - (62) + (63) - (66) + (67) - (71) + (72)$

22 $0 = +0.84 - (65) + (66) - (72) + (73) - (75) + (76)$

23 $0 = +0.28 - (73) + (74) + (75) - (78) - (79) + (80)$

24 $0 = -3.20 - (64) + (65) - (76) + (77) - (81) + (82)$

25 $0 = +0.42 - (77) + (78) - (80) + (81)$

26 $0 = -0.5 - 1.42\ (1) + 1.23\ (5) - 0.87\ (6) + 4.11\ (7) - 3.24\ (8) - 0.68\ (12) + 2.14\ (13)$
$- 1.46 (14)$

27 $0 = +1.5 + 4.29\ (1) - 2.87\ (2) - 0.58\ (3) + 1.99\ (4) - 2.91\ (11) + 3.59\ (12) - 0.68\ (14)$
$- 0.77\ (17) + 1.29\ (18) - 0.52\ (19) - 3.38\ (20) + 6.92\ (21) - 3.54\ (22)$

28 $0 = +2.5 - 3.12\ (15) + 5.46\ (16) - 2.34\ (17) - 2.08\ (22) + 3.37\ (23) - 1.29\ (24) + 0.66\ (25)$
$+ 1.03\ (26) - 1.69\ (27) - 3.21\ (33) + 3.48\ (34) - 0.27\ (35) - 1.15\ (40) + 5.78\ (41)$
$- 4.63\ (42)$

29 $0 = -6.9 - 1.80\ (35) + 3.73\ (36) - 1.93\ (37) - 2.09\ (38) + 2.97\ (39) - 0.88\ (40) - 1.73\ (49)$
$+ 2.61\ (50) - 0.88\ (52) - 1.15\ (55) - 1.61\ (57) - 0.46\ (58) - 1.92\ (59) + 6.23\ (60)$
$- 4.31\ (61)$

30 $0 = +7.7 - 12.99\ (50) + 13.87\ (51) - 0.88\ (52) - 1.15\ (55) + 8.53\ (56) - 7.38\ (57) - 1.92\ (59)$
$+ 6.23\ (60) - 4.31\ (61)$

31 $0 = +3.9 + 0.50\ (54) + 1.15\ (55) - 1.65\ (57) - 4.40\ (60) + 4.31\ (61) + 0.09\ (62) - 1.78\ (67)$
$+ 7.03\ (68) - 5.25\ (69)$

32 $0 = -5.6 - 2.71\ (46) + 3.69\ (47) - 0.98\ (48) - 0.88\ (50) + 4.59\ (52) - 3.71\ (53) - 3.47\ (66)$
$+ 5.25\ (67) - 1.78\ (68) - 2.24\ (70) + 5.14\ (71) - 2.90\ (72)$

33 $0 = +15.5 - 8.44\ (64) + 10.48\ (65) - 2.04\ (66) - 0.13\ (72) + 4.57\ (73) - 4.44\ (74) - 0.68\ (79)$
$+ 3.97\ (80) + 4.94\ (81) - 1.76\ (82)$

34 $0 = +0.7 - 2.87\ (1) + 2.87\ (2) - 1.41\ (4) + 0.87\ (6) - 0.87\ (7) - 0.39\ (9) + 0.39\ (10)$
$- 2.34\ (16) + 3.11\ (17) - 0.77\ (18) + 3.38\ (20) - 3.38\ (21) - 1.29\ (23) + 1.29\ (24)$
$- 0.10\ (28) + 0.10\ (29) - 2.90\ (31) + 2.90\ (32) + 3.21\ (33) - 3.21\ (34) - 1.93\ (36)$
$+ 193\ (37) - 0.88\ (39) + 2.03\ (40) - 1.15\ (41) + 1.06\ (43) - 1.06\ (44) - 0.98\ (47)$
$+ 0.98\ (48) + 1.73\ (49) - 1.73\ (50) - 3.71\ (52) + 3.71\ (53) + 1.92\ (59) - 1.92\ (60)$
$+ 0.88\ (62) - 0.88\ (63) - 2.04\ (65) + 5.51\ (66) - 3.47\ (67) + 2.24\ (70) - 2.24\ (71)$
$- 4.44\ (73) + 4.44\ (74) + 1.93\ (75) - 1.93\ (76) + 0.94\ (77) - 0.94\ (78) + 0.68\ (79)$
$- 0.68\ (80) - 3.18\ (81)$

(*c*) ***Figure adjustment***—Continued.

Correlate equations.

$(1) = +C_2 - C_4 - 1.42C_{26} + 4.29C_{27} - 2.87C_{34}$

$(2) = +C_4 - 2.87C_{27} + 2.87C_{34}$

$(3) = -C_1 - C_3 - 0.58C_{27}$

$(4) = -C_2 + C_3 + 1.99C_{27} - 1.41C_{34}$

$(5) = +C_1 + 1.23C_{26}$

$(6) = -C_2 + C_4 - 0.87C_{26} + 0.87C_{34}$

$(7) = +C_2 - C_3 + 4.11C_{26} - 0.87C_{34}$

$(8) = +C_3 - C_5 - 3.24C_{26}$

$(9) = +C_5 - C_6 - 0.39C_{34}$

$(10) = -C_4 + C_6 + 0.39C_{34}$

$(11) = -C_5 - 2.91C_{27}$

$(12) = -C_3 + C_5 - 0.68C_{26} + 3.59C_{27}$

$(13) = -C_1 + 2.14C_{26}$

$(14) = +C_1 + C_3 - 1.46C_{26} - 0.68C_{27}$

$(15) = -C_8 - 3.12C_{28}$

$(16) = -C_7 + C_8 + 5.46C_{28} - 2.34C_{34}$

$(17) = -C_6 + C_7 - 0.77C_{27} - 2.34C_{28} + 3.11C_{34}$

$(18) = -C_5 + C_6 + 1.29C_{27} - 0.77C_{34}$

$(19) = +C_5 - 0.52C_{27}$

$(20) = -C_4 - 3.38C_{27} + 3.38C_{34}$

$(21) = +C_4 - C_6 + 6.92C_{27} - 3.38C_{34}$

$(22) = +C_6 - C_7 - 3.54C_{27} - 2.08C_{28}$

$(23) = +C_7 - C_9 + 3.37C_{28} - 1.29C_{34}$

$(24) = +C_9 - 1.29C_{28} + 1.29C_{34}$

$(25) = -C_{10} + 0.66C_{28}$

$(26) = -C_8 + C_{10} + 1.03C_{28}$

$(27) = +C_8 - 1.69C_{28}$

$(28) = -C_7 + C_9 - 0.10C_{34}$

$(29) = +C_7 - C_8 + 0.10C_{34}$

$(30) = +C_8 - C_{10}$

$(31) = +C_{10} - C_{11} - 2.90C_{34}$

$(32) = -C_9 + C_{11} + 2.90C_{34}$

$(33) = -C_9 - 3.21C_{28} + 3.21C_{34}$

$(34) = +C_9 - C_{11} + 3.48C_{28} - 3.21C_{34}$

$(35) = +C_{11} - C_{12} - 0.27C_{28} - 1.80C_{29}$

$(36) = +C_{12} - C_{13} + 3.73C_{29} - 1.93C_{34}$

$(37) = +C_{13} - 1.93C_{29} + 1.93C_{34}$

$(38) = -C_{14} - 2.09C_{29}$

$(39) = -C_{12} + C_{14} + 2.97C_{29} - 0.88C_{34}$

$(40) = -C_{11} + C_{12} - 1.15C_{28} - 0.83C_{29} + 2.03C_{34}$

$(41) = -C_{10} + C_{11} + 5.78C_{28} - 1.15C_{34}$

$(42) = +C_{10} - 4.63C_{28}$

$(43) = -C_{12} + C_{13} + 1.06C_{34}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Completed.

$(44) = + C_{12} - C_{14} - 1.06C_{34}$

$(45) = + C_{14} - C_{17}$

$(46) = + C_{17} - C_{18} - 2.71C_{32}$

$(47) = - C_{15} + C_{18} + 3.69C_{32} - 0.98C_{34}$

$(48) = - C_{13} + C_{15} - 0.98C_{32} + 0.98C_{34}$

$(49) = - C_{13} - 1.73C_{29} + 1.73C_{34}$

$(50) = + C_{13} - C_{15} + 2.61C_{29} - 12.99C_{30} - 0.88C_{32} - 1.73C_{34}$

$(51) = - C_{16} + 13.87C_{30}$

$(52) = + C_{15} + C_{16} - C_{20} - 0.88C_{29} - 0.88C_{30} + 4.59C_{32} - 3.71C_{34}$

$(53) = + C_{20} - 3.71C_{32} + 3.71C_{34}$

$(54) = - C_{17} - C_{19} + 0.50C_{31}$

$(55) = - C_{16} + C_{19} - 1.15C_{29} - 1.15C_{30} + 1.15C_{31}$

$(56) = + C_{16} + 8.53C_{30}$

$(57) = - C_{14} + C_{17} + 1.61C_{29} - 7.38C_{30} - 1.65C_{31}$

$(58) = + C_{14} - 0.46C_{29}$

$(59) = - C_{15} - C_{16} + C_{20} - 1.92C_{29} - 1.92C_{30} + 1.92C_{34}$

$(60) = + C_{15} - C_{18} + 6.23C_{29} + 6.23C_{30} - 4.40C_{31} - 1.92C_{34}$

$(61) = + C_{16} - C_{19} - 4.31C_{29} - 4.31C_{30} + 4.31C_{31}$

$(62) = + C_{18} + C_{19} - C_{21} + 0.09C_{31} + 0.88C_{34}$

$(63) = - C_{20} + C_{21} - 0.88C_{34}$

$(64) = - C_{24} - 8.44C_{33}$

$(65) = - C_{22} + C_{24} + 10.48C_{33} - 2.04C_{34}$

$(66) = - C_{21} + C_{22} - 3.47C_{32} - 2.04C_{33} + 5.51C_{34}$

$(67) = - C_{18} - C_{19} + C_{21} - 1.78C_{31} + 5.25C_{32} - 3.47C_{34}$

$(68) = - C_{17} + C_{18} + 7.03C_{31} - 1.78C_{32}$

$(69) = + C_{17} + C_{19} - 5.25C_{31}$

$(70) = - C_{20} - 2.24C_{32} + 2.24C_{34}$

$(71) = + C_{20} - C_{21} + 5.14C_{32} - 2.24C_{34}$

$(72) = + C_{21} - C_{22} - 2.90C_{32} - 0.13C_{33}$

$(73) = + C_{22} - C_{23} + 4.57C_{33} - 4.44C_{34}$

$(74) = + C_{23} - 4.44C_{33} + 4.44C_{34}$

$(75) = - C_{22} + C_{23} + 1.93C_{34}$

$(76) = + C_{22} - C_{24} - 1.93C_{34}$

$(77) = + C_{24} - C_{25} + 0.94C_{34}$

$(78) = - C_{23} + C_{25} - 0.94C_{34}$

$(79) = - C_{23} - 0.68C_{33} + 0.68C_{34}$

$(80) = + C_{23} - C_{25} + 3.97C_{33} - 0.68C_{34}$

$(81) = - C_{24} + C_{25} + 4.94C_{33} - 3.18C_{34}$

$(82) = + C_{24} - 1.76C_{33}$

(*c*) *Figure adjustment*—Continued.

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
0 = −0·17	+4		+2											
+0·02		+4	−2	−2										
+0·69			+6		−2									
−0·18				+6		−2								
+1·22	...	...	...	...	+6	−2	...	...	...	...	...	...	...	...
−0·88						+6	−2							
−0·86							+6	−2	−2					
+1·37								+6		−2				
+0·65									+6		−2			
−0·64	...	...	...	...	...	...	...	...	...	+6	−2	...	...	...
+0·47											+6	−2		
−1·11												+6	−2	−2
+0·83													+6	
−0·25														+6

Normal equations—Continued.

	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}
−0·17												−2·37	−0·10
+0·02												+3·56	+2·30
+0·69												−8·13	−1·70
−0·18												+0·55	+3·14
+1·22	...	...	...	...	...	...	...	...	...	...	...	+2·56	+4·69
−0·88													−8·40
−0·86													+2·77
+0·83	−2												
−0·25			−2										
0 = −1·05	+6	+2	...	−2	...	−2	...	...	...	...	...	....	....
−2·15		+6			−2	−2							
−1·06			+6	−2	+2								
−0·20				+6	+2		−2						
−0·43					+6		−2						
−0·58	...	...	...	...	...	+6	−2		...	...	...	....	....
+1·06							+6	−2					
−0·84								+6	−2	−2			
+0·28									+6		−2		
−3·20										+6	−2		
+0·42	...	...	...	...	...	...	...	...	...	...	+4	....	....
−0·5												+38·850	−7·540
+1·5													+127·126

(*c*) *Figure adjustment*—Continued.

Normal equations—Continued.

	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}	C_{34}
− 0·17							
+ 0·02							− 3·20
+ 0·69							− 0·54
− 0·18							− 0·54
+ 1·22	....	....	....	....	....	....	+ 0·38
− 0·88	+ 0·26						+ 0·28
− 0·86	− 2·35						+ 4·36
+ 1·37	+ 5·86						− 2·44
+ 0·65	+ 2·03						− 6·84
− 0·64	−10·04	....	....	....	....	....	− 1·75
+ 0·47	+ 3·18	− 0·92					+ 5·83
− 1·11	− 0·88	+ 1·68					− 1·14
+ 0·83		− 1·32	−12·99		+ 0·10		+ 0·48
− 0·25	....	+ 2·99	+ 7·38	+ 1·65	....	....	+ 0·18
− 1·05		+ 4·66	+20·26	− 4·40	+ 0·80		− 3·86
− 2·15		− 2·12	− 7·46	+ 3·16	+ 4·59		− 5·63
− 1·06		+ 1·61	− 7·38	−14·43	− 0·93		
− 0·20		− 6·23	− 6·23	+13·30	− 0·63		+ 5·29
− 0·43		+ 3·16	+ 3·16	− 7·04	− 5·25		+ 4·35
− 0·58	....	− 1·04	− 1·04	....	− 0·92	....	+ 5·74
+ 1·06				− 1·87	+ 0·68	+ 1·91	− 8·50
+ 0·84					− 0·57	− 7·82	− 0·75
+ 0·28						− 4·36	+10·39
− 3·20						+12·22	+ 4·01
+ 0·42	....	....	....	....	....	+ 0·97	− 4·38
− 0·5							− 0·257
+ 1·5	+ 9·165						−61·557
o=+ 2·5	+145·377	+ 1·498					−56·522
− 6·9		+110·622	+17·387	−49·967	− 6·336		−35·215
+ 7·7	....	....	+551·515	−35·134	+ 7·392	....	+10·090
+ 3·9				+122·391	−21·858		+14·704
− 5·6					+140·146	+ 7·456	−87·716
+15·5						+269·566	−91·495
+ 0·7							+276·196

Resulting values of correlates.

$C_1=+0·252$	$C_{10}=-0·044$	$C_{19}=-0·106$	$C_{28}=-0·048\ 1$
$C_2=-0·283$	$C_{11}=+0·089$	$C_{20}=+0·394$	$C_{29}=+0·021\ 5$
$C_3=-0·463$	$C_{12}=+0·288$	$C_{21}=-0·015$	$C_{30}=-0·013\ 8$
$C_4=-0·041$	$C_{13}=+0·050$	$C_{22}=+0·091$	$C_{31}=-0·035\ 2$
$C_5=-0·292$	$C_{14}=+0·272$	$C_{23}=+0·227$	$C_{32}=-0·033\ 2$
$C_6=+0·004$	$C_{15}=+0·324$	$C_{24}=+1·070$	$C_{33}=-0·137\ 9$
$C_7=-0·114$	$C_{16}=+0·277$	$C_{25}=+0·456$	$C_{34}=-0·110\ 6$
$C_8=-0·203$	$C_{17}=+0·346$	$C_{26}=-0·034\ 2$	
$C_9=-0·150$	$C_{18}=+0·467$	$C_{27}=-0·055\ 2$	

Resulting corrections to angular directions.

″	″	″	″
(1)=−0·113	(22)=+0·185	(43)=−0·355	(64)=+0·094
(2)=−0·200	(23)=+0·243	(44)=+0·133	(65)=−0·241
(3)=+0·242	(24)=−0·231	(45)=−0·074	(66)=−0·107
(4)=−0·134	(25)=+0·012	(46)=−0·031	(67)=−0·104
(5)=+0·210	(26)=+0·110	(47)=+0·129	(68)=−0·067
(6)=+0·176	(27)=−0·122	(48)=+0·198	(69)=+0·425
(7)=+0·136	(28)=−0·253	(49)=−0·278	(70)=−0·567
(8)=−0·060	(29)=+0·306	(50)=+0·182	(71)=+0·486
(9)=−0·253	(30)=−0·159	(51)=−0·468	(72)=+0·008
(10)=+0·002	(31)=+0·188	(52)=+0·458	(73)=−0·275
(11)=+0·453	(32)=−0·082	(53)=+0·107	(74)=+0·348
(12)=−0·004	(33)=−0·051	(54)=−0·258	(75)=−0·078
(13)= 0·325	(34)=−0·051	(55)=−0·432	(76)=−0·765
(14)=−0·124	(35)=−0·225	(56)=+0·159	(77)=+0·510
(15)=+0·353	(36)=+0·532	(57)=+0·269	(78)=+0·333
(16)=−0·321	(37)=−0·205	(58)=+0·262	(79)= 0·208
(17)=−0·079	(38)=−0·317	(59)= 0·434	(80)=−0·701
(18)=+0·310	(39)=+0·145	(60)=+0·272	(81)=−0·944
(19)=−0·263	(40)=+0·011	(61)=+0·198	(82)=+1·313
(20)=−0·146	(41)=−0·018	(62)=+0·276	
(21)=−0·053	(42)=+0·179	(63)=−0·312	

(*d*) *Adjusted triangles, Indiana.*

No.	Stations.	Observed angles.			Correc-tions.	Spher-ical angles.	Spher-ical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
1	Honey Creek	67	33	52·33	−0·04	52·29	0·75	4·535 016 4	34 278·07
	Claremont	56	06	20·71	−0·11	20·60	0·74	4·488 312 1	30 783·08
	Hunt City	56	19	49·21	+0·13	49·34	0·74	4·489 451 3	30 863·94
				02·25			2·23		
2	Belle Air	72	14	07·11	−0·12	06·99	0·44	4·488 312 1	30 783·08
	Honey Creek	33	04	17·16	−0·20	16·96	0·44	4·246 469 9	17 638·83
	Hunt City	74	41	37·75	−0·37	37·38	0·45	4·493 845 4	31 177·79
				02·02			1·33		

(*d*) *Adjusted triangles, Indiana*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
3	Belle Air	44	32	07·61	+0·20	07·81	0·21	4·156 114 3	14 325·65
	Oblong	59	43	05·85	+0·21	06·06	0·21	4·246 470 0	17 638·84
	Hunt City	75	44	46·99	−0·24	46·75	0·20	4·296 599 3	19 797·00
				00·45			0·62		
4	Summit	31	53	44·32	+0·09	44·41	0·84	4·489 451 3	30 863·94
	Claremont	36	17	07·72	−0·09	07·63	0·84	4·538 691 3	34 569·36
	Honey Creek	111	49	10·30	+0·18	10·48	0·84	4·734 229 1	54 228·69
				02·34			2·52		
5	Merom College	69	46	58·20	+0·39	58·59	0·54	4·538 691 3	34 569·36
	Summit	30	45	12·94	+0·24	13·18	0·54	4·275 022 9	18 837·48
	Honey Creek	79	27	49·61	+0·25	49·86	0·55	4·558 923 3	36 217·90
				00·75			1·63		
6	Merom College	76	01	27·12	−0·57	26·55	0·46	4·493 845 4	31 177·79
	Honey Creek	68	04	50·60	−0·19	50·41	0·46	4·474 308 2	29 806·31
	Belle Air	35	53	44·88	−0·46	44·42	0·46	4·275 022 9	18 837·48
				02·60			1·38		
7	Sisson	92	48	04·55	+0·56	05·11	0·52	4·558 923 3	36 217·90
	Summit	45	14	01·05	+0·06	01·11	0·53	4·410 690 3	25 744·85
	Merom College	41	57	55·12	+0·24	55·36	0·53	4·384 660 6	24 247·75
				00·72			1·58		
8	Wright	51	14	20·94	−0·23	20·71	0·40	4·410 690 3	25 744·85
	Sisson	94	44	28·80	−0·47	28·33	0·40	4·517 238 6	32 903·23
	Merom College	34	01	12·83	−0·67	12·16	0·40	4·266 512 7	18 471·95
				02·57			1·20		
9	Osborn	33	15	22·24	0·00	22·24	0·77	4·384 660 6	24 247·75
	Summit	58	27	44·67	−0·48	44·19	0·77	4·576 168 2	37 684·97
	Sisson	88	16	56·06	−0·17	55·89	0·78	4·645 383 5	44 196·05
				02·97			2·32		
10	Calvary	61	24	44·79	−0·03	44·76	0·80	4·576 168 2	37 684·97
	Osborn	82	37	14·18	−0·17	14·01	0·79	4·629 019 3	42 561·74
	Sisson	35	58	03·89	−0·27	03·62	0·80	4·401 510 5	25 206·38
				02·86			2·39		
11	Calvary	24	28	39·20	+0·20	39·40	0·50	4·266 512 7	18 471·95
	Sisson	48	12	26·70	+0·34	27·04	0·50	4·521 644 2	33 238·72
	Wright	107	18	54·95	+0·10	55·05	0·49	4·629 019 4	42 561·75
				00·85			1·49		

(*d*) *Adjusted triangles, Indiana*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
12	Beard	63	13	47·81	+0·49	48·30	0·43	4·401 510 5	25 206·38
	Osborn	49	22	10·43	+0·76	11·19	0·42	4·330 945 7	21 426·23
	Calvary	67	24	01·92	−0·14	01·78	0·42	4·416 047 7	26 064·40
				00·16			1·27		
13	Rariden	50	35	10·48	+0·46	10·94	0·54	4·416 047 7	26 064·40
	Osborn	47	24	31·76	−0·74	31·02	0·54	4·395 097 8	24 836·93
	Beard	82	00	20·22	−0·55	19·67	0·55	4·523 862 1	33 408·89
				02·46			1·63		
14	Leonard	13	51	33·21	+0·11	33·32	0·13	4·395 097 8	24 836·93
	Rariden	8	38	02·96	−0·65	02·31	0·12	4·192 166 7	15 565·63
	Beard	157	30	24·47	+0·28	24·75	0·13	4·598 439 6	39 667·94
				00·64			0·38		
15	Leonard	77	33	20·87	−0·01	20·86	0·23	4·330 945 7	21 426·23
	Beard	57	15	27·50	−0·20	27·30	0·24	4·266 123 5	18 455·40
	Calvary	45	11	12·09	+0·46	12·55	0·24	4·192 166 6	15 565·63
				00·46			0·71		
16	Fountain	47	34	42·06	+0·71	42·77	0·59	4·395 097 8	24 836·93
	Rariden	67	27	44·85	+0·27	45·12	0·59	4·492 420 3	31 075·66
	Beard	64	57	33·82	+0·07	33·89	0·60	4·484 054 7	30 482·79
				00·73			1·78		
17	Fountain	73	39	37·18	+0·63	37·81	0·87	4·598 439·6	39 667·94
	Rariden	58	49	41·89	+0·93	42·82	0·88	4·548 625 7	35 369·24
	Leonard	47	30	41·41	+0·59	42·00	0·88	4·484 054 9	30 482·80
				00·48			2·63		
18	Fountain	26	04	55·12	−0·07	55·05	0·41	4·192 166 7	15 565·63
	Beard	92	32	50·65	+0·21	50·86	0·41	4·548 625 8	35 369·24
	Leonard	61	22	14·62	+0·70	15·32	0·41	4·492 420 4	31 075·66
				00·39			1·23		
19	Weed Patch	49	41	20·54	+0·04	20·58	0·66	4·492 420 4	31 075·66
	Fountain	92	27	53·19	0·00	53·19	0·66	4·609 754 3	40 714·99
	Beard	37	50	48·04	+0·16	48·20	0·65	4·398 005 3	25 003·76
				01·77			1·97		
20	Weed Patch	71	30	53·17	+0·53	53·70	0·68	4·548 625 7	35 369·24
	Fountain	66	22	58·07	+0·08	58·15	0·69	4·533 641 7	34 169·74
	Leonard	42	06	10·39	−0·18	10·21	0·69	4·398 005 3	25 003·76
				01·63			2·06		

(*d*) *Adjusted triangles, Indiana*—Completed.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
21	Weed Patch	21	49	32·63	+0·49	33·12	0·44	4·192 166 7	15 565·63
	Beard	54	42	02·61	+0·04	02·65	0·44	4·533 641 5	34 169·72
	Leonard	103	28	25·01	+0·53	25·54	0·43	4·609 754 2	40 714·98
				00·25			1·31		
22	Miller	43	09	39·95	+1·05	41·00	0·54	4·484 054 8	30 482·80
	Rariden	29	36	04·70	−0·35	04·35	0·54	4·342 654 5	22 011·75
	Fountain	107	14	16·40	−0·12	16·28	0·55	4·629 006 0	42 560·43
				01·05			1·63		
23	Miller	36	03	56·66	−0·48	56·18	0·43	4·398 005 3	25 003·76
	Fountain	112	43	08·35	−0·58	07·77	0·43	4·593 029 1	39 176·81
	Weed Patch	31	12	57·34	0·00	57·34	0·43	4·342 654 4	22 011·74
				02·35			1·29		
24	Tripp	47	35	33·62	−0·69	32·93	1·26	4·593 029 1	39 176·81
	Miller	86	25	35·79	−0·28	35·51	1·27	4·723 914 1	52 955·87
	Weed Patch	45	58	55·22	+0·13	55·35	1·26	4·581 559 4	38 155·70
				04·63			3·79		
25	Tripp	113	56	39·86	−0·18	39·68	0·23	4·453 827 3	28 433·30
	Green	33	30	15·37	−0·94	14·43	0·22	4·234 844 1	17 172·92
	Stout	32	33	05·86	+0·70	06·56	0·22	4·223 741 2	16 739·45
				01·09			0·67		
26	Tripp	82	25	52·05	−0·41	51·64	0·55	4·599 073 6	39 725·89
	Stout	72	11	45·04	−0·49	44·55	0·55	4·581 559 5	38 155·71
	Miller	25	22	24·84	+0·62	25·46	0·55	4·234 844 1	17 172·92
				01·93			1·65		
27	Tripp	116	01	54·47	+1·28	55·75	0·68	4·793 440 5	62 149·90
	Weed Patch	14	00	20·83	−0·34	20·49	0·67	4·223 741 1	16 739·45
	Green	49	57	43·52	+2·26	45·78	0·67	4·723 914 1	52 955·87
				58·82			2·02		

(*e*) *Precision of the Indiana series of triangles.*

The probable error in length of any side of the series of triangles due to the angular measures may be found as usual by the formulæ:

$$m=\sqrt{2\frac{[vv]}{c}},\ u_{\underset{n}{a}}=\tfrac{2}{3}(\delta_{\underset{n}{a}})^{-2}\Sigma_{a_1}^{a_n}[\delta_A^2+\delta_A\,\delta_B+\delta_B^2] \text{ and } e_{\underset{n}{a}}=0{\cdot}674\ 5m\sqrt{u_{\underset{n}{a}}}$$

To this must be added the probable error due to that of the side of the base net.

From the solution of 34 normal equations involving 82 directions we have $m=\pm 0''{\cdot}72$.

The side Calvary to Osborn is selected as dividing the series into two nearly equal parts. $\delta_{a_n} = 17{\cdot}2$ in units of the sixth place of decimals in the logarithm. Starting from the side Green to Stout of the Holton Base Net, we have $\Sigma = 99{\cdot}0$ (8 triangles), $e_{a_n} = \pm 0{\cdot}228$ metre, $e_b = \pm 0{\cdot}080$ metre, and $e_1 = \pm 0{\cdot}242$ metre. Starting from the side Hunt City to Claremont of the Olney Base Net $\Sigma = 69{\cdot}6$ (6 triangles), $e_{a_n} = \pm 0{\cdot}192$ metre, $e_b = \pm 0{\cdot}088$ metre, and $e_2 = \pm 0{\cdot}211$ metre. Then the probable error in length of Calvary to Osborn as a side of the adjusted triangulation is found by the expression $e = \frac{e_1 e_2}{\sqrt{e_1^2 + e_2^2}}$ $= \pm 0{\cdot}159$ metre, or about $\frac{1}{159\,000}$ part of the length.

The effect on the arc is approximately (the distances being measured on the thirty-ninth parallel between the projections of the middle points of the terminal lines) as follows:

Terminal lines.	Distances.	Probable errors.		Average.	
	km.				*m.*
Green-Stout to Calvary-Osborn	113	$\frac{1}{313\,900}$	$\frac{1}{159\,000}$	$\frac{1}{211\,000}$	$\pm 0{\cdot}54$
Calvary-Osborn to Hunt City-Claremont	102	$\frac{1}{159\,000}$	$\frac{1}{285\,800}$	$\frac{1}{204\,000}$	$\pm 0{\cdot}50$
	215			Sum	$\pm 1{\cdot}04$

5. THE ILLINOIS SERIES OF TRIANGLES. 1880–81–82–83.

(*a*) *Introduction.*

This series forms the connection of the Olney Base, measured by the United States Lake Survey, and the American Bottom Base east of St. Louis, Missouri. The distance along the axis of the triangulation between Newton and Clarks Mound is about 172 kilometres (107 statute miles); the number of intermediate stations is 12, and the average length of a side is 29 kilometres (18 statute miles); the average number of series observed (mean of telescope *D.* and *R.*) at a station is 103, and the number of positions of the circle 17.

The observations were made by G. A. Fairfield, J. B. Weir, and F. W. Perkins, assistants. The theodolite* was mounted at all the stations on scaffolds with an average elevation above the ground of 18·1 metres. Respecting the physical aspects of the country traversed by this series, the observer, Assistant G. A. Fairfield, remarks as follows:

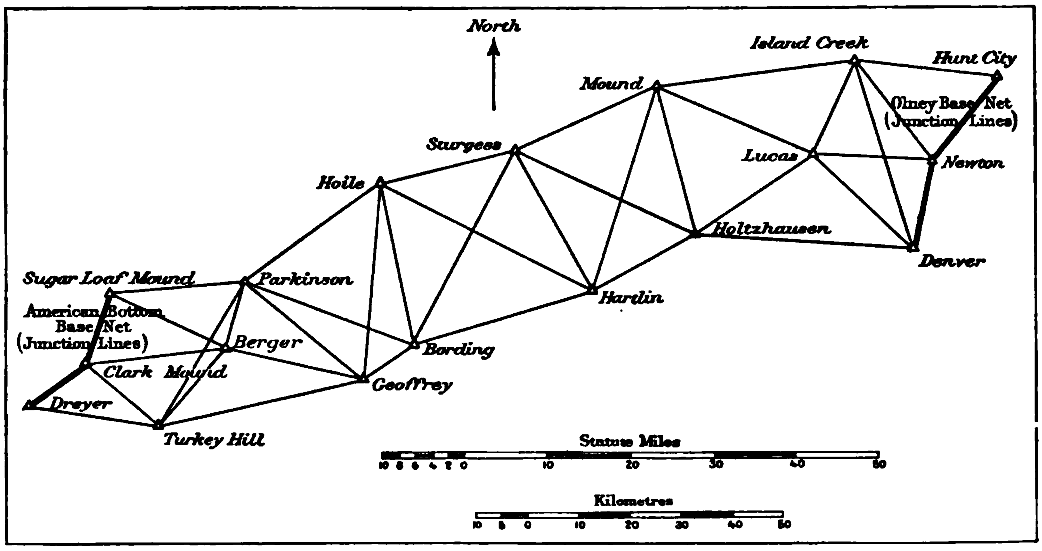
> The great plane which stretches across Illinois, in the vicinity of the thirty-ninth parallel, from the bluffs, rising from the eastern edge of the Great American Bottom, to the Wabash River, may best be described as a slightly undulating prairie, more or less deeply scored by river and creek bottoms. The diversity of the surface is almost entirely due to erosion. The average elevation of the line above sea level is about 500 feet; the western half being somewhat above that figure, while the eastern half, which gradually slopes to the Wabash, falls somewhat below it.
>
> The forests are scanty and of recent growth, except in the deeper bottoms, and the trees, which are mainly confined to the slopes, rarely exceed 75 feet in height. The summit levels are for the most part flat and under cultivation. The great economy of building to overlook the trees in a flat

* The diameter of the horizontal circle of the theodolites employed in the work is given in connection with the abstract of resulting directions.

country, rather than cutting lines, being well established, towers were used at all the stations, their height being governed by that of the trees of the region. Where a natural elevation existed, the height of the towers was correspondingly less.

During the first season, in 1880, observations were made on poles; after that all observations were made on lights at night.

No. 30.



The adjustment of the figure involves 33 conditions to be satisfied, of which two are necessary to preserve the length and relative distance of the base net sides and one the accord in length between the two measured base lines.*

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880–81–82–83.*

Dreyer, St. Clair County, Illinois. October 26 to October 27, 1871. 30-centimetre theodolite, No. 32. O. H. Tittmann and R. E. Halter, observers. June 20, 1873. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer. November 19 to December 1, 1880. 30-centimetre theodolite. No. 107. Telescope above ground in 1880, 10·67 metres. G. A. Fairfield, observer.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustments.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Kleinschmidt	0	00	00·00	±0·19	+0·77		00·77
	Insane Asylum	56	04	42·32	0·10	−1·40		40·92
	Standpipe	85	08	41·16	0·09			
	Clarks Mound	140	08	32·76	0·14	+0·63		33·39
1	Turkey Hill	184	06	27·79	0·32		−0·99	26·80
						Mean	0·00	

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·98.

*In these equations plane angles were used to obviate the reduction from arc to sine.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880–81–82–83*—Continued.

Sugar Loaf Mound, Madison County, Illinois. May 12 to May 24, 1873. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer. September 13 to September 24, 1880. 30-centimetre theodolite, No. 107. Telescope above ground 14·20 metres in 1880. G. A. Fairfield, observer.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrretions from base-net and figure adjustments.	Final seconds in triangulation.
		°	′	″	″	″	″	″
4	Parkinson	0	00	00·00	±0·20		−0·08	59·92
5	Berger	30	24	26·70	0·19		−0·24	26·46
	American Bottom Lower Base	114	53	21·82	0·20	+0·09		21·91
	Clarks Mound	117	35	06·48	0·11	−0·24		06·24
	Insane Asylum	161	07	27·22	0·23	−0·33		26·89
	Standpipe	174	35	29·21	0·13			
	Minoma	185	11	47·19	0·22	+0·48		47·67
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·20.

Clarks Mound, St. Clair County, Illinois. October 13 to November 10, 1871. 30-centimetre theodolite, No. 32. O. H. Tittmann and R. E. Halter, observers. May 28 to May 31, 1873. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer. August 13 to September 4, 1880. 30-centimetre theodolite, No. 107. Telescope above ground in 1880 10·52 metres. G. A. Fairfield, observer.

	Objects observed.	°	′	″	″	″	″	″
	Dreyer	0	00	00·00	±0·13	+0·39		00·39
	Kleinschmidt	17	23	30·35	0·18	−1·80		28·55
	Insane Asylum	46	08	58·34	0·10	+0·75		59·09
	Minoma	73	51	07·94	0·31	+0·73		08·67
	Standpipe	77	38	29·97	0·14			
	Sugar Loaf Mound	149	26	05·45	0·12	+0·95		06·40
	American Bottom Upper Base	154	17	03·14	0·17	−1·02		02·12
2	Berger	210	04	34·22	0·23		+0·95	35·17
3	Turkey Hill	256	01	11·05	0·19		+0·12	11·17
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·39.

Turkey Hill, St. Clair County, Illinois. October 7 to November 6, 1880. 30-centimetre theodolite, No. 107. Telescope above ground 11·73 metres. G. A. Fairfield, observer.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
9	Berger	0	00	00·00	±0·10	+0·05	00·05
10	Geoffrey	37	59	37·77	0·16	−0·69	37·08
6	Dreyer	236	15	04·35	0·21	+0·23	04·58
7	Clarks Mound	268	18	22·39	0·12	+0·20	22·59
8	Parkinson	350	58	00·59	0·13	+0·21	00·80

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·32.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880–81–82–83*—Continued.

Berger, St. Clair County, Illinois. July 15 to August 6, 1881. 30-centimetre theodolite, No. 135. Telescope above ground 14·17 metres. G. A. Fairfield, observer.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
14	Parkinson	0	00	00·00	±0·15	−0·49	59·51
15	Geoffrey	86	24	46·21	0·17	+0·62	46·83
11	Turkey Hill	202	36	51·15	0·20	−0·14	51·01
12	Clarks Mound	244	58	38·47	0·12	−0·01	38·46
13	Sugar Loaf Mound	277	09	30·78	0·17	+0·02	30·80

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·01.

Parkinson, Madison County, Illinois. August 21 to September 28, 1881. 30-centimetre theodolite, No. 135. Telescope above ground 14·17 metres. G. A. Fairfield, observer.

		°	′	″	″	″	″
19	Berger	0	00	00·00	±0·12	+0·63	00·63
20	Turkey Hill	13	34	53·38	0·16	−0·25	53·13
21	Sugar Loaf Mound	66	45	06·36	0·13	−0·18	06·18
16	Hoile	216	12	16·97	0·13	−0·12	16·85
17	Bording	273	04	28·03	0·16	+0·08	28·11
18	Geoffrey	292	20	45·52	0·14	−0·15	45·37

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·86.

Geoffrey, Clinton County, Illinois. October 19 to November 6, 1881. 30-centimetre theodolite, No. 135. Telescope above ground 11·13 metres. J. B. Weir, observer.

		°	′	″	″	″	″
26	Bording	0	00	00·00	±0·11	−0·14	59·86
22	Turkey Hill	205	10	07·46	0·13	+0·18	07·64
23	Berger	230	58	27·72	0·18	−0·04	27·68
24	Parkinson	256	54	26·39	0·13	−0·36	26·03
25	Hoile	311	32	40·14	0·16	+0·36	40·50

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·86.

Bording, Clinton County, Illinois. September 18 to October 9, 1882. 30-centimetre theodolite, No. 135. Telescope above ground 14·17 metres. G. A. Fairfield, J. B. Weir, and T. P. Borden, observers.

		°	′	″	″	″	″
27	Geoffrey	0	90	00·00	±0·11	+0·06	00·06
28	Parkinson	57	38	09·67	0·16	+0·15	09·82
29	Hoile	115	35	28·24	0·17	−0·18	28·06
30	Sturgess	155	38	41·89	0·22	+0·20	42·09
31	Hartlin	200	01	46·38	0·18	−0·22	46·16

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·03.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880–81–82–83*—Continued.

Hoile, Bond County, Illinois. July 25 to September 3, 1882. 30-centimetre theodolite, No. 135. Telescope above ground 23·32 metres. G. A. Fairfield and J. B. Weir, observers.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
34	Bording	0	00	00·00	±0·13	+0·19	00·19
35	Geoffrey	15	57	13·76	0·10	−0·07	13·69
36	Parkinson	65	10	33·01	0·20	+0·08	33·09
32	Sturgess	268	23	18·60	0·20	+0·10	18·70
33	Hartlin	307	17	51·56	0·17	−0·30	51·26

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·98.

Hartlin, Marion County, Illinois. November 23 to December 3, 1882. 30-centimetre theodolite, No. 135. Telescope above ground 23·32 metres. G. A. Fairfield and J. B. Weir, observers.

		°	′	″	″	″	″
41	Holtzhausen	0	00	00·00	±0·17	−0·26	$\overline{59}$·74
37	Bording	190	34	08·10	0·16	+0·43	08·53
38	Hoile	233	25	44·75	0·22	−0·22	44·53
39	Sturgess	267	44	09·19	0·12	+0·06	09·13
40	Mound	315	20	07·87	0·17	+0·11	07·98

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·00.

Sturgess, Fayette County, Illinois. May 27 to June 11, 1883. 30-centimetre theodolite, No. 135. Telescope above ground 23·32 metres. G. A. Fairfield, observer.

		°	′	″	″	″	″
46	Hoile	0	00	00·00	±0·18	+0·16	00·16
42	Mound	167	20	00·18	0·16	+0·09	00·27
43	Holtzhausen	217	22	57·05	0·18	+0·31	57·36
44	Hartlin	253	12	55·20	0·13	+0·06	55·26
45	Bording	311	39	54·04	0·16	−0·61	53·43

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·97.

Holtzhausen, Fayette County, Illinois. August 6 to August 21, 1883. 30-centimetre theodolite, No. 135. Telescope above ground 23·32 metres. G. A. Fairfield and F. W. Perkins, observers.

		°	′	″	″	″	″
47	Hartlin	0	00	00·00	±0·14	+0·05	00·05
48	Sturgess	51	54	13·23	0·20	+0·09	13·32
49	Mound	103	36	04·93	0·17	−0·16	04·77
50	Lucas	172	53	41·45	0·16	+0·34	41·79
51	Denver	210	56	39·07	0·16	−0·33	38·74

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·01.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880–81–82–83*—Continued.

Mound, Effingham County, Illinois. June 27 to July 30, 1883. 30-centimetre theodolite, No. 135. Telescope above ground 24·84 metres. G. A. Fairfield and F. W. Perkins, observers.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
54	Holtzhausen	0	00	00·00	±0·10	−0·24	59·76
55	Hartlin	31	44	04·62	0·16	+0·37	04·99
56	Sturgess	78	15	13·84	0·17	−0·25	13·59
52	Island Creek	277	13	07·08	0·18	−0·04	07·04
53	Lucas	309	09	08·76	0·21	+0·17	08·93

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·07.

Lucas, Effingham County, Illinois. August 26 to September 3, 1883. 30-centimetre theodolite, No. 135. Telescope above ground 23·32 metres. G. A. Fairfield and F. W. Perkins, observers.

		°	′	″	″	″	″
57	Holtzhausen	0	00	00·00	±0·14	−0·16	59·84
58	Mound	59	51	33·87	0·18	+0·10	33·97
59	Island Creek	148	08	01·22	0·20	+0·52	01·74
60	Newton	217	04	41·30	0·15	−0·70	40·60
61	Denver	257	34	15·15	0·14	+0·25	15·40

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·96.

Island Creek, Jasper County, Illinois. September 9 to September 25, 1883. 30-centimetre theodolite, No. 135. Telescope above ground 24·84 metres. G. A. Fairfield and F. W. Perkins, observers.

		°	′	″	″	″	″
63	Newton	0	00	00·00	±0·09	−0·36	59·64
64	Denver	20	39	49·53	0·20	+0·25	49·78
65	Lucas	61	23	49·69	0·15	+0·13	49·82
66	Mound	121	11	22·01	0·18	−0·16	21·85
62	Hunt City	315	08	57·40	0·16	+0·14	57·54

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·99.

Newton, Jasper County, Illinois. October 3 to October 16, 1883. 30-centimetre theodolite, No. 135. Telescope above ground, 12·65 metres. G. A. Fairfield, observer.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Denver	0	00	00·00	±0·10	−0·13		59·87
70	Lucas	79	44	13·01	0·26		−0·07	12·94
71	Island Creek	129	23	45·69	0·18		−0·69	45·00
	Hunt City	205	20	35·47	0·18	+0·46		35·93
	Claremont	307	38	00·83	0·15	−0·32		00·51
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·00.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880–81–82–83*—Continued.

Denver, Richland County, Illinois. November, 1879. 35-centimetre theodolite, Troughton and Simms, No. 3. R. S. Woodward, observer, United States Lake Survey. November 12 to December 2, 1883. 30-centimetre theodolite, No. 135. Telescope above ground in 1879 and 1883, 23·16 metres. G. A. Fairfield, observer.

	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Newton	0	00	00·00	±0·09	+0·70		00·70
	Onion Hill	19	57	16·27		+0·09		16·36
	Buffalo Mound	29	06	41·03		−0·16		40·87
	Olney West Base	30	07	07·33		−0·19		07·14
	Claremont	80	43	13·71	0·18	−0·44		13·27
	Parkersburg	129	20	12·16				
67	Holtzhausen	260	42	27·11	0·18		+0·03	27·14
68	Lucas	300	13	46·61	0·18		+0·94	47·55
69	Island Creek	330	03	35·36	0·16		−0·24	35·12
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·01 in 1883.

Hunt City, Jasper County, Illinois. October, 1879. 35-centimetre theodolite, Troughton and Simms, No. 3. R. S. Woodward, observer, United States Lake Survey. September 5 to September 7, 1884. 30-centimetre theodolite, No. 107. Telescope above ground in 1879 and 1884 23·32 metres. G. A. Fairfield, observer.

		°	′	″	″	″	″	″
	Belle Air	0	00	00·00	±0·16			
	Honey Creek	74	41	37·75	0·20			
	Oblong	75	44	47·03		+0·12		47·15
	Claremont	131	01	27·19	0·27	−0·07		27·12
	Buffalo Mound	145	05	08·91		−0·12		08·79
	Newton	173	22	02·19	0·19	+0·07		02·26
72	Island Creek	232	34	09·67	0·23		+0·80	10·47
	Casey	313	18	25·33				
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·25 in 1884.

(*c*) *Figure adjustment.*

Observation equations.

No.	
1	$0 = -1·14 + (1) - (3) - (6) + (7)$
2	$0 = -1·22 + (2) - (5) - (12) + (13)$
3	$0 = +0·84 - (2) + (3) - (7) + (9) - (11) + (12)$
4	$0 = +1·49 - (4) + (5) - (13) + (14) - (19) + (21)$
5	$0 = +1·72 - (9) + (10) + (11) - (15) - (22) + (23)$
6	$0 = -1·57 - (14) + (15) - (18) + (19) - (23) + (24)$
7	$0 = +1·54 - (8) + (10) - (18) + (20) - (22) + (24)$

(*c*) *Figure adjustment*—Continued.

Observation equations—Completed.

No.	
8	$0 = -0.10 - (17) + (18) - (24) + (26) - (27) + (28)$
9	$0 = -0.85 - (16) + (18) - (24) + (25) - (35) + (36)$
10	$0 = +0.25 - (16) + (17) - (28) + (29) - (34) + (36)$
11	$0 = -1.23 - (29) + (30) - (32) + (34) - (45) + (46)$
12	$0 = +0.21 - (29) + (31) - (33) + (34) - (37) + (38)$
13	$0 = +1.58 - (30) + (31) - (37) + (39) - (44) + (45)$
14	$0 = +0.41 - (39) + (41) - (43) + (44) - (47) + (48)$
15	$0 = +0.49 - (39) + (40) - (42) + (44) - (55) + (56)$
16	$0 = +0.04 - (42) + (43) - (48) + (49) - (54) + (56)$
17	$0 = -0.35 - (49) + (50) - (53) + (54) - (57) + (58)$
18	$0 = -0.34 - (52) + (53) - (58) + (59) - (65) + (66)$
19	$0 = +0.17 - (50) + (51) + (57) - (61) - (67) + (68)$
20	$0 = +1.34 - (59) + (60) - (63) + (65) - (70) + (71)$
21	$0 = +0.06 - (60) + (61) - (68) + (70)$
22	$0 = -0.16 - (63) + (64) - (69) + (71)$
23	$0 = -0.99 - (62) + (63) - (71) + (72)$
24	$0 = +2.3 + 2.18\,(1) + 0.10\,(5) + 3.36\,(6) - 3.30\,(7) - 0.06\,(9) + 2.30\,(11) - 5.64\,(12) + 3.34\,(13)$
25	$0 = -6.1 + 3.22\,(2) - 2.03\,(3) - 3.58\,(4) + 3.68\,(5) + 0.06\,(7) + 2.64\,(9) - 2.70\,(10) - 0.87\,(18) + 1.78\,(19) - 0.91\,(21) - 4.36\,(22) + 8.69\,(23) - 4.33\,(24)$
26	$0 = -8.8 - 13.25\,(8) + 15.95\,(9) - 2.70\,(10) - 0.87\,(18) + 9.59\,(19) - 8.72\,(20) - 4.36\,(22) + 8.69\,(23) - 4.33\,(24)$
27	$0 = -0.6 - 1.38\,(16) + 7.41\,(17) - 6.03\,(18) + 0.49\,(24) + 1.87\,(25) - 2.36\,(26) - 6.39\,(34) + 7.36\,(35) - 0.97\,(36)$
28	$0 = -0.1 - 2.51\,(29) + 4.66\,(30) - 2.15\,(31) - 2.67\,(32) + 2.61\,(33) + 0.06\,(34) - 0.48\,(37) + 3.09\,(38) - 2.61\,(39)$
29	$0 = -4.0 + 0.08\,(39) + 2.13\,(40) - 2.21\,(41) - 1.76\,(42) + 4.68\,(43) - 2.92\,(44) - 2.97\,(54) + 3.41\,(55) - 0.44\,(56)$
30	$0 = -10.3 - 0.80\,(49) + 3.49\,(50) - 2.69\,(51) - 3.38\,(52) + 5.09\,(53) - 1.71\,(54) - 2.45\,(64) + 3.67\,(65) - 1.22\,(66) - 2.55\,(67) + 6.22\,(68) - 3.67\,(69)$
31	$0 = +2.5 - 0.81\,(59) + 3.28\,(60) - 2.47\,(61) - 4.43\,(63) + 5.58\,(64) - 1.15\,(65) - 1.22\,(68) + 3.66\,(69)$
32	$0 = +4.6 - 2.12\,(62) + 7.70\,(63) - 5.58\,(64) - 3.66\,(69) - 1.25\,(72)$
33	$0 = -0.3 + 1.19\,(2) - 3.58\,(4) + 3.58\,(5) + 3.34\,(12) - 3.34\,(13) - 0.13\,(14) + 0.13\,(15) - 1.38\,(16) + 1.38\,(17) + 0.91\,(19) - 0.91\,(21) + 4.33\,(23) - 3.84\,(24) - 0.49\,(26) + 1.33\,(27) - 1.33\,(28) - 2.15\,(30) + 2.15\,(31) + 0.06\,(32) + 0.91\,(34) - 0.97\,(36) + 0.48\,(37) - 0.40\,(39) - 0.08\,(41) - 1.76\,(42) + 1.76\,(43) + 1.87\,(45) - 1.87\,(46) + 1.65\,(47) - 1.65\,(48) - 0.80\,(49) + 0.80\,(50) - 3.38\,(52) + 3.38\,(53) + 0.44\,(54) - 0.44\,(56) + 1.22\,(57) - 1.22\,(58) - 0.81\,(59) + 0.81\,(60) - 2.12\,(62) + (2.12\,(63) + 1.22\,(65) - 1.22\,(66) + 1.79\,(70) - 1.79\,(71) - 1.25\,(72)$

(*c*) *Figure adjustment*—Continued.

Correlate equations.

$(1) = +C_1 + 2.18C_{24}$

$(2) = +C_2 - C_3 + 3.22C_{25} + 1.19C_{33}$

$(3) = -C_1 + C_3 - 2.03C_{25}$

$(4) = -C_4 - 3.58C_{25} - 3.58C_{33}$

$(5) = -C_2 + C_4 + 0.10C_{24} + 3.68C_{25} + 3.58C_{33}$

$(6) = -C_1 + 3.36C_{24}$

$(7) = +C_1 - C_3 - 3.30C_{24} + 0.06C_{25}$

$(8) = -C_7 - 13.25C_{26}$

$(9) = +C_3 - C_5 - 0.06C_{24} - 2.64C_{25} + 15.95C_{26}$

$(10) = +C_5 + C_7 - 2.70C_{25} - 2.70C_{26}$

$(11) = -C_3 + C_5 + 2.30C_{24}$

$(12) = -C_2 + C_3 - 5.64C_{24} - 3.34C_{33}$

$(13) = +C_2 - C_4 + 3.34C_{24} - 3.34C_{33}$

$(14) = +C_4 - C_6 - 0.13C_{33}$

$(15) = -C_5 + C_6 + 0.13C_{33}$

$(16) = -C_9 - C_{10} - 1.38C_{27} - 1.38C_{33}$

$(17) = -C_8 + C_{10} + 7.41C_{27}$

$(18) = -C_6 - C_7 + C_8 + C_9 - 0.87C_{25} - 0.87C_{26} - 6.03C_{27}$

$(19) = -C_4 + C_6 + 1.78C_{25} + 9.59C_{26} + 0.91C_{33}$

$(20) = +C_7 - 8.72C_{26}$

$(21) = +C_4 - 0.91C_{25} - 0.91C_{33}$

$(22) = -C_5 - C_7 - 4.36C_{25} - 4.36C_{26}$

$(23) = +C_5 - C_6 + 8.69C_{25} + 8.69C_{26} + 4.33C_{33}$

$(24) = +C_6 + C_7 - C_8 - C_9 - 4.33C_{25} - 4.33C_{26} + 0.49C_{27} - 3.84C_{33}$

$(25) = +C_9 + 1.87C_{27}$

$(26) = +C_8 - 2.36C_{27} - 0.49C_{33}$

$(27) = -C_8 + 1.33C_{33}$

$(28) = +C_8 - C_{10} - 1.33C_{33}$

$(29) = +C_{10} - C_{11} - C_{12} - 2.51C_{28}$

$(30) = +C_{11} - C_{13} + 4.66C_{28} - 2.15C_{33}$

$(31) = +C_{12} + C_{13} - 2.15C_{28} - 2.15C_{33}$

$(32) = -C_{11} - 2.67C_{28} + 0.06C_{33}$

$(33) = -C_{12} + 2.61C_{28}$

$(34) = -C_{10} + C_{11} + C_{12} - 6.39C_{27} + 0.06C_{28} + 0.91C_{33}$

$(35) = -C_9 + 7.36C_{27}$

$(36) = +C_9 + C_{10} - 0.97C_{27} - 0.97C_{33}$

$(37) = -C_{12} - C_{13} - 0.48C_{28} + 0.48C_{33}$

$(38) = +C_{12} + 3.09C_{28}$

$(39) = +C_{13} - C_{14} - C_{15} - 2.61C_{28} + 0.08C_{29} - 0.40C_{33}$

$(40) = +C_{15} + 2.13C_{29}$

$(41) = +C_{14} - 2.21C_{29} - 0.08C_{33}$

$(42) = -C_{15} - C_{16} - 1.76C_{29} - 1.76C_{33}$

$(43) = -C_{14} + C_{16} + 4.68C_{29} + 1.76C_{33}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Completed.

$(44) = -C_{13} + C_{14} + C_{15} - 2{\cdot}92C_{29}$
$(45) = -C_{11} + C_{13} + 1{\cdot}87C_{33}$
$(46) = +C_{11} - 1{\cdot}87C_{33}$
$(47) = -C_{14} + 1{\cdot}65C_{33}$
$(48) = +C_{14} - C_{16} - 1{\cdot}65C_{33}$
$(49) = +C_{16} - C_{17} - 0{\cdot}80C_{30} - 0{\cdot}80C_{33}$
$(50) = +C_{17} - C_{19} + 3{\cdot}49C_{30} + 0{\cdot}80C_{33}$
$(51) = +C_{19} - 2{\cdot}69C_{30}$
$(52) = -C_{18} - 3{\cdot}38C_{30} - 3{\cdot}38C_{33}$
$(53) = -C_{17} + C_{18} + 5{\cdot}09C_{30} + 3{\cdot}38C_{33}$
$(54) = -C_{16} + C_{17} - 2{\cdot}97C_{29} - 1{\cdot}71C_{30} + 0{\cdot}44C_{33}$
$(55) = -C_{15} + 3{\cdot}41C_{29}$
$(56) = +C_{15} + C_{16} - 0{\cdot}44C_{29} - 0{\cdot}44C_{33}$
$(57) = -C_{17} + C_{19} + 1{\cdot}22C_{33}$
$(58) = +C_{17} - C_{18} - 1{\cdot}22C_{33}$
$(59) = +C_{18} - C_{20} - 0{\cdot}81C_{31} - 0{\cdot}81C_{33}$
$(60) = +C_{20} - C_{21} + 3{\cdot}28C_{31} + 0{\cdot}81C_{33}$
$(61) = -C_{19} + C_{21} - 2{\cdot}47C_{31}$
$(62) = -C_{23} - 2{\cdot}12C_{32} - 2{\cdot}12C_{33}$
$(63) = -C_{20} - C_{22} + C_{23} - 4{\cdot}43C_{31} + 7{\cdot}70C_{32} + 2{\cdot}12C_{33}$
$(64) = +C_{22} - 2{\cdot}45C_{30} + 5{\cdot}58C_{31} - 5{\cdot}58C_{32}$
$(65) = -C_{18} + C_{20} + 3{\cdot}67C_{30} - 1{\cdot}15C_{31} + 1{\cdot}22C_{33}$
$(66) = +C_{18} - 1{\cdot}22C_{30} - 1{\cdot}22C_{33}$
$(67) = -C_{19} - 2{\cdot}55C_{30}$
$(68) = +C_{19} - C_{21} + 6{\cdot}22C_{30} - 1{\cdot}22C_{31}$
$(69) = -C_{22} - 3{\cdot}67C_{30} + 3{\cdot}66C_{31} - 3{\cdot}66C_{32}$
$(70) = -C_{20} + C_{21} + 1{\cdot}79C_{33}$
$(71) = +C_{20} + C_{22} - C_{23} - 1{\cdot}79C_{33}$
$(72) = +C_{23} - 1{\cdot}25C_{32} - 1{\cdot}25C_{33}$

(*c*) *Figure adjustment*—Continued.

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
0=+1·14	+4		−2											
−1·22		+4	−2	−2										
+0·84			+6		−2									
+1·49				+6		−2								
+1·72	...	...	...	...	+6	−2	+2	...	...	...	...	...	...	...
−1·57						+6	+2	−2	−2					
+1·54							+6	−2	−2					
−0·10								+6	+2	−2				
−0·85									+6	+2				
+0·25	...	...	...	...	...	...	...	...	...	+6	−2	−2	...	...
−1·23											+6	+2	−2	
+0·21												+6	+2	
+1·58													+6	−2
+0·41														+6

Normal equations—Continued.

	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}
+1·14										−4·48	+ 2·09	
−1·22										+8·88	− 0·46	
+0·84										−4·70	− 2·67	+15·95
+1·49										−3·24	+ 4·57	− 9·59
+1·72	...	...	...	...	...	...	...	...	...	+2·36	+ 7·71	− 5·60
−1·57											−10·37	− 2·56
+1·54											− 1·80	+ 2·73
−0·10											+ 3·46	+ 3·46
−0·85											+ 3·46	+ 3·46
+1·58	−2											
+0·41	+2	−2										
0=+0·49	+6	+2	...	...	...	...	...	...	...	....	....	....
+0·04		+6	−2									
−0·35			+6	−2	−2							
−0·34				+6		−2						
+0·17					+6		−2					
+1·34	...	...	...	...	...	+6	−2	+2	−2	....	....	....
+0·06							+4					
−0·16								+4	−2			
−0·99									+4			
+2·3										+75·20	+ 0·01	− 0·96
−6·1	...	....	...	...	...	...	...	...	...	....	+173·14	+180·50
−8·8												+719·29

(*c*) *Figure adjustment*—Continued.

Normal equations—Completed.

	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}
+ 1·14							
− 1·22							− 9·07
+ 0·84							+ 2·15
+ 1·49							+ 8·55
+ 1·72	....	....	....	....	....	....	+ 4·20
− 1·57	+ 6·52						− 7·00
+ 1·54	+ 6·52						− 3·84
− 0·10	−16·29						− 0·69
− 0·85	−11·60						+ 4·25
+ 0·25	+14·21	−2·57	....	....	....	....	+ 2·21
− 1·23	− 6·39	+9·90					− 5·04
+ 0·21	− 6·39	+1·38					+ 2·58
+ 1·58		−8·94	+3·00				+ 5·29
+ 0·41		+2·61	−9·89				− 4·74
+ 0·49	....	+2·61	−2·96	....	....	....	+ 1·72
+ 0·04			+8·97	+0·91			+ 3·49
− 0·35			−2·97	−2·51			− 3·78
− 0·34				+3·58	+0·34		+ 4·73
+ 0·17				+2·59	+1·25		+ 0·42
+ 1·34	....	....	....	+3·67	+7·37	−7·70	− 2·86
+ 0·06				−6·22	−4·53		+ 0·98
− 0·16				+1·22	+6·35	−9·62	− 3·91
− 0·99					−4·43	+8·57	+ 4·78
+ 2·3							− 29·64
− 6·1	+ 3·12	....	....	....	....	....	+ 86·53
− 8·8	+ 3·12						+ 62·98
0=− 0·6	+198·42	− 0·38					+ 6·53
− 0·1		+63·17	− 0·21				− 13·93
− 4·0			+63·60	+ 5·08			+ 10·37
−10·3	....	....	....	+139·93	−38·91	+ 27·10	+ 37·27
+ 2·5					+84·48	− 78·64	− 7·48
+ 4·6						+109·88	+ 22·38
− 0·3							+170·92

Resulting values of correlates.

C_{1} = −0·690 6	C_{12} = +0·060 7	C_{23} = +0·452 1
C_{2} = +0·310 8	C_{13} = −0·453 5	C_{24} = −0·137 6
C_{3} = −0·429 2	C_{14} = −0·070 4	C_{25} = +0·070 7
C_{4} = −0·130 3	C_{15} = −0·077 2	C_{26} = +0·002 1
C_{5} = −0·255 4	C_{16} = −0·142 0	C_{27} = +0·031 2
C_{6} = +0·364 8	C_{17} = −0·023 2	C_{28} = −0·089 7
C_{7} = −0·236 7	C_{18} = −0·105 7	C_{29} = +0·085 9
C_{8} = −0·070 6	C_{19} = −0·172 7	C_{30} = +0·057 2
C_{9} = +0·304 8	C_{20} = −0·429 2	C_{31} = −0·226 0
C_{10} = −0·209 4	C_{21} = −0·479 9	C_{32} = −0·265 6
C_{11} = +0·134 7	C_{22} = +0·171 1	C_{33} = −0·012 34

Corrections to angular directions.

″	″	″	″
(1) = −0·991	(19) = +0·630	(37) = +0·430	(55) = +0·370
(2) = +0·953	(20) = −0·253	(38) = −0·216	(56) = −0·252
(3) = +0·118	(21) = −0·183	(39) = −0·061	(57) = −0·165
(4) = −0·079	(22) = +0·175	(40) = +0·106	(58) = +0·098
(5) = −0·239	(23) = −0·041	(41) = −0·259	(59) = +0·516
(6) = +0·229	(24) = −0·359	(42) = +0·090	(60) = −0·700
(7) = +0·196	(25) = +0·363	(43) = +0·308	(61) = +0·251
(8) = +0·209	(26) = −0·139	(44) = +0·055	(62) = +0·137
(9) = +0·054	(27) = +0·055	(45) = −0·611	(63) = −0·360
(10) = −0·689	(28) = +0·154	(46) = +0·158	(64) = +0·252
(11) = −0·142	(29) = −0·180	(47) = +0·050	(65) = +0·132
(12) = −0·005	(30) = +0·196	(48) = +0·092	(66) = −0·161
(13) = +0·022	(31) = −0·225	(49) = −0·155	(67) = +0·026
(14) = −0·493	(32) = +0·103	(50) = +0·340	(68) = +0·939
(15) = +0·618	(33) = −0·295	(51) = −0·327	(69) = −0·236
(16) = −0·122	(34) = +0·190	(52) = −0·045	(70) = −0·073
(17) = +0·076	(35) = −0·075	(53) = +0·166	(71) = −0·688
(18) = −0·146	(36) = +0·078	(54) = −0·239	(72) = +0·799

(*d*) *Adjusted triangles, Illinois.*

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
1	Turkey Hill	32	03	18·04	−0·03	18·01	0·21	4·149 726 7	14 116·49
	Dreyer	43	57	54·40	−0·99	53·41	0·21	4·266 345 9	18 464·86
	Clarks Mound	103	58	49·34	−0·12	49·22	0·22	4·411 792 5	25 810·27
				01·78			0·64		
2	Berger	42	21	47·32	+0·14	47·46	0·31	4·266 345 9	18 464·86
	Turkey Hill	91	41	37·61	−0·14	37·47	0·30	4·437 608 1	27 391·01
	Clarks Mound	45	56	36·83	−0·84	35·99	0·31	4·294 316 0	19 693·19
				01·76			0·92		

(*d*) *Adjusted triangles, Illinois*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
3	Berger	32	10	52·31	+0·03	52·34	0·30	4·164 534 3	14 606·10
	Clarks Mound	60	38	27·82	+0·95	28·77	0·30	4·378 436 0	23 902·10
	Sugar Loaf Mound	87	10	39·54	+0·24	39·78	0·29	4·437 608 0	27 391·01
				59·67			0·89		
4	Parkinson	13	34	53·38	−0·88	52·50	0·09	4·294 316 0	19 693·19
	Berger	157	23	08·85	−0·35	08·50	0·08	4·508 500 2	32 247·81
	Turkey Hill	9	01	59·41	−0·16	59·25	0·08	4·119 488 0	13 167·04
				01·64			0·25		
5	Parkinson	66	45	06·36	−0·81	05·55	0·26	4·378 436 0	23 902·10
	Berger	82	50	29·22	−0·52	28·70	0·26	4·411 815 7	25 811·64
	Sugar Loaf Mound	30	24	26·70	−0·16	26·54	0·27	4·119 488 1	13 167·04
				02·28			0·79		
6	Geoffrey	25	48	20·26	−0·22	20·04	0·41	4·294 316 0	19 693·19
	Turkey Hill	37	59	37·77	−0·74	37·03	0·42	4·444 789 5	27 847·71
	Berger	116	12	04·94	−0·76	04·18	0·42	4·608 424 2	40 590·48
				02·97			1·25		
7	Geoffrey	51	44	18·93	−0·53	18·40	0·81	4·508 500 2	32 247·81
	Turkey Hill	47	01	37·18	−0·90	36·28	0·81	4·477 840 4	30 049·72
	Parkinson	81	14	07·86	−0·11	07·75	0·81	4·608 424 2	40 590·48
				03·97			2·43		
8	Geoffrey	25	55	58·67	−0·32	58·35	0·31	4·119 488 0	13 167·04
	Berger	86	24	46·21	+1·11	47·32	0·31	4·477 840 5	30 049·72
	Parkinson	67	39	14·48	+0·78	15·26	0·31	4·444 789 6	27 847·72
				59·36			0·93		
9	Hoile	49	13	19·25	+0·15	19·40	0·80	4·477 840 4	30 049·72
	Geoffrey	54	38	13·75	+0·72	14·47	0·80	4·510 030 1	32 361·61
	Parkinson	76	08	28·55	−0·02	28·53	0·80	4·585 773 7	38 527·75
				01·55			2·40		
10	Bording	57	38	09·67	+0·10	09·77	0·29	4·477 840 4	30 049·72
	Geoffrey	103	05	33·61	+0·22	33·83	0·29	4·539 717 6	34 651·14
	Parkinson	19	16	17·49	−0·22	17·27	0·29	4·069 726 9	11 741·59
				00·77			0·87		
11	Bording	115	35	28·24	−0·24	28·00	0·29	4·585 773 7	38 527·75
	Geoffrey	48	27	19·86	−0·50	19·36	0·29	4·504 771 4	31 972·12
	Hoile	15	57	13·76	−0·26	13·50	0·28	4·069 726 8	11 741·59
				01·86			0·86		

(*d*) *Adjusted triangles, Illinois*—Continued.

No.	Stations.	Observed angles. °	′	″	Correction. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
12	Bording	57	57	18·57	−0·34	18·23	0·80	4·510 030 1	32 361·61
	Parkinson	56	52	11·06	+0·20	11·26	0·80	4·504 771 4	31 972·12
	Hoile	65	10	33·01	−0·11	32·90	0·79	4·539 717 5	34 651·14
				02·64			2·39		
13	Hartlin	42	51	36·65	−0·65	36·00	1·00	4·504 771 4	31 972·12
	Bording	84	26	18·14	−0·05	18·09	1·01	4·670 081 6	46 782·30
	Hoile	52	42	08·44	+0·49	08·93	1·01	4·572 769 5	37 391·21
				03·23			3·02		
14	Sturgess	58	26	58·84	−0·67	58·17	0·95	4·572 769 5	37 391·21
	Hartlin	77	09	61·09	−0·49	60·60	0·94	4·631 253 3	42 781·24
	Bording	44	23	04·49	−0·42	04·07	0·95	4·487 006 6	30 690·69
				04·42			2·84		
15	Sturgess	106	47	04·80	+0·10	04·90	0·68	4·670 081 6	46 782·30
	Hartlin	34	18	24·44	+0·16	24·60	0·69	4·439 977 1	27 540·84
	Hoile	38	54	32·96	−0·40	32·56	0·69	4·487 006 6	30 690·69
				02·20			2·06		
16	Sturgess	48	20	05·96	+0·77	06·73	0·75	4·504 771 4	31 972·12
	Bording	40	03	13·65	+0·37	14·02	0·75	4·439 977 0	27 540·83
	Hoile	91	36	41·40	+0·09	41·49	0·74	4·631 253 3	42 781·24
				01·01			2·24		
17	Holtzhausen	51	54	13·23	+0·04	13·27	0·59	4·487 006 6	30 690·69
	Hartlin	92	15	50·81	−0·20	50·61	0·60	4·590 707 7	38 967·96
	Sturgess	35	49	58·15	−0·25	57·90	0·59	4·358 513 5	22 830·40
				02·19			1·78		
18	Mound	31	44	04·62	+0·61	05·23	0·57	4·358 513 5	22 830·40
	Holtzhausen	103	36	04·93	−0·21	04·72	0·57	4·625 186 2	42 187·74
	Hartlin	44	39	52·13	−0·36	51·77	0·58	4·484 464 3	30 511·55
				01·68			1·72		
19	Mound	78	15	13·84	−0·01	13·83	0·79	4·590 707 7	38 967·96
	Holtzhausen	51	41	51·70	−0·25	51·45	0·79	4·494 629 6	31 234·14
	Sturgess	50	02	56·87	+0·22	57·09	0·79	4·484 464 4	30 511·56
				02·41			2·37		
20	Mound	46	31	09·22	−0·62	08·60	0·81	4·487 006 6	30 690·69
	Hartlin	47	35	58·68	+0·17	58·85	0·81	4·494 629 4	31 234·13
	Sturgess	85	52	55·02	−0·04	54·98	0·81	4·625 186 1	42 187·73
				02·92			2·43		

(*d*) *Adjusted triangles, Illinois*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
21	Lucas	40	29	33·85	+0·95	34·80	0·34	4·242 702 7	17 486·49
	Newton	79	44	13·14	−0·07	13·07	0·34	4·423 216 3	26 498·20
	Denver	59	46	14·09	−0·94	13·15	0·34	4·366 741 7	23 267·07
				01·08			1·02		
22	Lucas	102	25	44·85	−0·41	44·44	0·60	4·623 100 2	41 985·58
	Denver	39	31	19·50	+0·91	20·41	0·60	4·437 113 8	27 359·86
	Holtzhausen	38	02	57·62	−0·67	56·95	0·60	4·423 216 3	26 498·20
				01·97			1·80		
23	Lucas	59	51	33·87	+0·26	34·13	0·66	4·484 464 4	30 511·56
	Holtzhausen	69	17	36·52	+0·50	37·02	0·66	4·518 550 3	33 002·76
	Mound	50	50	51·24	−0·41	50·83	0·66	4·437 113 9	27 359·86
				01·63			1·98		
24	Island Creek	44	51	02·60	−0·50	02·10	0·41	4·307 622 1	20 305·89
	Hunt City	59	12	07·41	+0·80	08·21	0·41	4·393 256 1	24 731·82
	Newton	75	56	50·24	+0·69	50·93	0·42	4·446 078 0	27 930·46
				00·25			1·24		
25	Island Creek	20	39	49·53	+0·61	50·14	0·28	4·242 702 7	17 486·49
	Newton	129	23	45·82	−0·69	45·13	0·28	4·583 126 1	38 293·59
	Denver	29	56	25·34	+0·24	25·58	0·29	4·393 256 2	24 731·83
				00·69			0·85		
26	Island Creek	61	23	49·69	+0·49	50·18	0·37	4·366 741 7	23 267·07
	Newton	49	39	32·68	−0·61	32·07	0·37	4·305 338 0	20 199·38
	Lucas	68	56	40·08	−1·22	38·86	0·37	4·393 256 0	24 731·82
				02·45			1·11		
27	Island Creek	40	43	60·16	−0·12	60·04	0·43	4·423 216 3	26 498·20
	Denver	29	49	48·75	−1·18	47·57	0·42	4·305 337 9	20 199·37
	Lucas	109	26	13·93	−0·26	13·67	0·43	4·583 125 9	38 293·58
				02·84			1·28		
28	Island Creek	59	47	32·32	−0·29	32·03	0·56	4·518 550 3	33 002·76
	Lucas	88	16	27·35	+0·42	27·77	0·57	4·581 736 3	38 171·25
	Mound	31	56	01·68	+0·21	01·89	0·56	4·305 337 9	20 199·37
				01·35			1·69		

(*e*) *The precision of the Illinois series.*

A proper measure of the precision of this triangulation may be had by considering it in three parts with dividing lines Mound to Holtzhausen and Parkinson to Geoffrey, and computing the probable error of these sides. To do this, we start from the side of the base net Hunt City to Newton and, following the triangles (as already used in the establishment of the length equation between the base nets), compute the probable error of the two sides. Next we repeat the same, starting from the opposite base net, and add for each line its respective weights to obtain its resulting probable error.

In the first place, we have for the mean error of an observed angle from $[vv] = 8{\cdot}88$ (as found from the 72 values of v) and from the 33 conditions—

$$m = \sqrt{\frac{2 \times 8{\cdot}88}{33}} = \pm 0''{\cdot}734$$

and we have given from the adjustments of the base nets:

	m.	*m.*	
Hunt City to Newton	$= 20\ 305{\cdot}89$	$\pm 0{\cdot}07$	Probable error $= \frac{1}{290\ 000}$ part.
Sugar Loaf Mound to Clarks Mound	$= 14\ 606{\cdot}10$	$\pm 0{\cdot}19$	Probable error $= \frac{1}{76\ 900}$ part.

We also have for—

Mound to Holtzhausen	$\log s = 4{\cdot}484\ 46$	and	$\delta_a = 14{\cdot}2$ (units of sixth place of logs.).
Parkinson to Geoffrey	$\log s = 4{\cdot}477\ 84$		$\delta_a = 14{\cdot}5$

Then for the probable error of the division line Mound to Holtzhausen:

Proceeding *westward* with $f(A, B)$* $= 33{\cdot}6$, the probable error—

$$\pm 0{\cdot}165 \text{ and } \frac{30\ 512}{20\ 306} \times 0{\cdot}07 = \pm 0{\cdot}105$$

hence probable error $\pm 0{\cdot}196$ metre and $p = 26{\cdot}0$. Similarly proceeding ***eastward*** with $f(A, B) = 76{\cdot}5$, the probable error—

$$\pm 0{\cdot}249 \text{ and } \frac{30\ 512}{14\ 606} \times 0{\cdot}19 = \pm 0{\cdot}40$$

hence probable error $\pm 0{\cdot}471$ metre and $p = 4{\cdot}5$ and after addition of the weights the probable error of the side becomes $\pm 0{\cdot}181$ metre and $\frac{s}{e} = \frac{1}{169\ 000}$ part. Likewise we have for the probable error of the other division line Parkinson to Geoffrey:

Proceeding *westward* with $f(A, B) = 57{\cdot}1$, the probable error—

$$\pm 0{\cdot}211 \text{ and } \frac{30\ 050}{20\ 306} \times 0{\cdot}07 = \pm 0{\cdot}104$$

---

*An abbreviation for $\Sigma \left[\delta_A^2 + \delta_A \delta_B + \delta_B^2\right]$

hence probable error $\pm 0{\cdot}235$ and $p = 18{\cdot}1$. Similarly proceeding ***eastward*** with $f(A, B) = 53{\cdot}0$, the probable error—

$$\pm 0{\cdot}203 \text{ and } \frac{30\ 050}{14\ 606} \times 0{\cdot}19 = \pm 0{\cdot}391$$

hence probable error $\pm 0{\cdot}441$ and $p = 5{\cdot}1$, and after adding the weights the probable error of the side becomes $\pm 0{\cdot}208$ and $\frac{s}{e} = \frac{1}{144\ 000}$ part.

The effect on the triangulation when projected on the thirty-ninth parallel becomes—

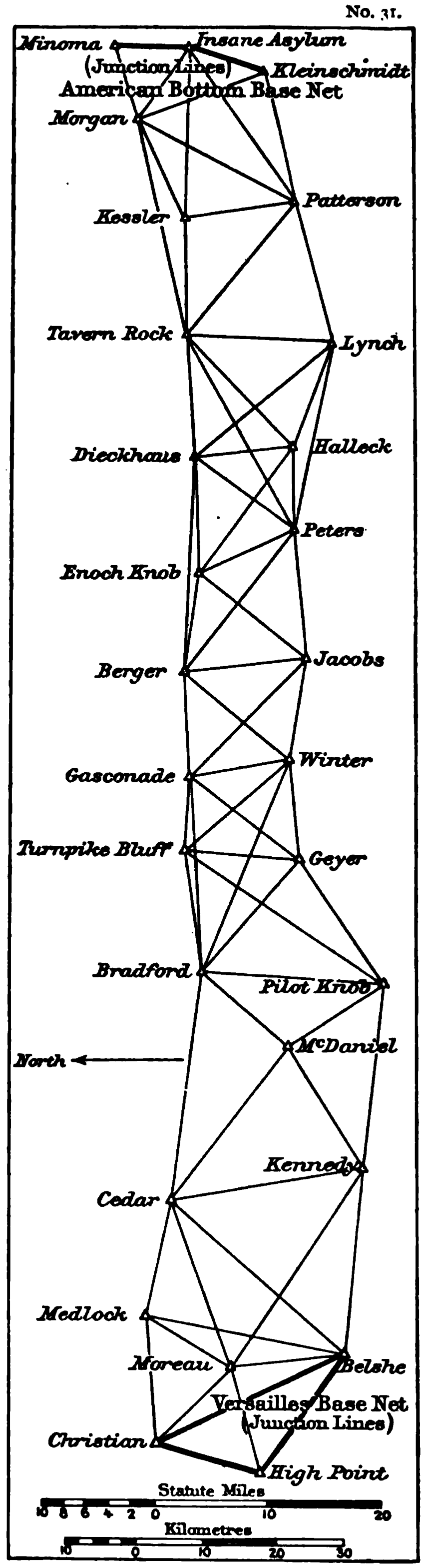
Terminal lines.	Distance.	Probable errors.		Average.	Effect on parts.
	km.				*m.*
Hunt City to Newton, and Mound to Holtzhausen	56	$\frac{1}{290\ 000}$	$\frac{1}{169\ 000}$	$\frac{1}{211\ 000}$	$\pm 0{\cdot}26$
Mound to Holtzhausen and Parkinson to Geoffrey	73	$\frac{1}{169\ 000}$	$\frac{1}{144\ 000}$	$\frac{1}{156\ 000}$	$\pm 0{\cdot}47$
Parkinson to Geoffrey, and Sugar Loaf Mound to Clark's Mound	43	$\frac{1}{144\ 000}$	$\frac{1}{76\ 000}$	$\frac{1}{103\ 000}$	$\pm 0{\cdot}43$
Sum	172			Total	$\pm 1{\cdot}16$

6. THE MISSOURI SERIES OF TRIANGLES, 1873–74, 1878–79.

(*a*) *Introduction.*

The measures of the horizontal directions of the triangulation connecting the American Bottom Base Net near St. Louis, Missouri, with the Versailles Base Net, Missouri, a distance of 195 kilometres, or about 121 statute miles, were made by three observers at different times between the years 1873 and 1879. It is here that the least width of the belt of triangulation between the eastern and western coasts occurs. This is due to the general flatness of the country and the desire to strengthen the connection by quadrilaterals or other complex figures, though in one case (the only instance in the whole arc) the distances and angles had to be carried forward across a single but well shaped triangle. The average length of sides is 20·6 kilometres or 12·8 statute miles. Between the two base nets there is a gradual ascent of the ground from about 450 feet near St. Louis to somewhat over 1 000 feet near Versailles. The country is for the most part under cultivation, and sufficiently timbered to offer obstacles to the triangulation. The observers, C. H. Van Orden, C. H. Boyd, and H. W. Blair, had about equal shares in the measures. The theodolite was generally mounted on scaffolds of no great height, about 10 metres, more or less.

No. 31.


Minoma
Insane Asylum
(Junction Lines)
Kleinschmidt
American Bottom Base Net
Morgan
Patterson
Kessler
Tavern Rock
Lynch
Dieckhaus
Halleck
Peters
Enoch Knob
Jacobs
Berger
Winter
Gasconade
Turnpike Bluff
Geyer
Bradford
Pilot Knob
McDaniel
North
Kennedy
Cedar
Medlock
Moreau
Belshe
Versailles Base Net
(Junction Lines)
Christian
High Point
Statute Miles
Kilometres

(*b*) *Abstracts of resulting horizontal directions at each station from local and from figure adjustments, 1873–74, 1878–79.*

Insane Asylum, St. Louis County, Missouri. November 8 to November 10, 1871. 30-centimetre theodolite, No. 14. W. Eimbeck, observer. October 2 to October 12, 1872. 25-centimetre theodolite, No. 92. C. H. Van Orden, observer. June 5 to June 23, 1873. 28-centimetre theodolite, No. 100. C. H. Boyd and C. H. Van Orden, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
	Minoma	0	00	00·00	−0·27		59·73
	Standpipe	39	46	44·35			
	Sugar Loaf Mound	65	21	06·63	+1·27		07·90
	American Bottom Upper Base	73	46	19·17	−0·88		18·29
	American Bottom Lower Base	89	50	07·81	−1·00		06·81
	Clarks Mound	98	31	40·32	+0·29		40·61
	Dreyer	148	18	49·26	+0·66		49·92
	Kleinschmidt	200	16	12·64	−0·07		12·57
4	Patterson	235	18	46·97		−0·69	46·28
5	Kessler	271	34	38·11		−0·25	37·86
6	Morgan	306	29	30·88		−0·05	30·83
				Mean	0·00		

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) = ± 1″·30.

Kleinschmidt, St. Louis County, Missouri. November 21 to December 9, 1871. 30-centimetre theodolite, No. 32. W. Eimbeck, observer. June 21 to June 22, 1873. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
2	Patterson	0	00	00·00		+0·50	00·50
3	Morgan	85	05	58·51		+1·86	60·37
	Insane Asylum	124	05	37·73	+0·58		38·31
	Azimuth Mark	124	37	35·99			
	Standpipe	132	54	24·14			
	Clarks Mound	173	35	37·11	−0·76		36·35
	Dreyer	196	03	35·63	+0·19		35·82
				Mean	0·00		

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) = ± 0″·90.

Minoma, St. Louis County, Missouri. June 5 to June 11, 1873. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
	Sugar Loaf Mound	0	00	00·00	−1·20		58·80
	American Bottom Upper Base	10	18	59·95	+1·60		61·55
	Standpipe	28	11	26·91			
	American Bottom Lower Base	28	30	38·95	+0·52		39·47
	Clarks Mound	36	48	21·53	−1·08		20·45
	Insane Asylum	90	34	30·33	+0·16		30·49
1	Morgan	164	32	12·93		−0·58	12·35
				Mean	0·00		

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) = ± 0″·84.

(*b*) *Abstracts of resulting horizontal directions at each station from local and from figure adjustments, 1873–74, 1878–79*—Continued.

Morgan, St. Louis County, Missouri. September 27 to October 22, 1873. 25-centimetre theodolite, No. 74. Telescope above ground 10·52 metres. C. H. Boyd and C. H. Van Orden, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
7	Minoma	0 00 00·00	+1·34	01·34
	Standpipe	16 54 26·04		
8	Insane Asylum	52 31 52·47	−1·61	50·86
9	Kleinschmidt	87 18 55·15	−0·13	55·02
10	Patterson	133 25 24·59	−0·01	24·58
11	Kessler	171 03 46·94	+0·90	47·84
12	Tavern Rock	182 45 28·84	−0·49	28·35

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) = ± 1″·31.

Kessler, St. Louis County, Missouri. September 22 to October 14, 1873. 28-centimetre theodolite, No. 100. C. H. Boyd, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
19	Morgan	0 00 00·00	−0·35	59·65
20	Insane Asylum	26 33 09·78	+0·38	10·16
21	Patterson	104 31 57·30	−0·51	56·79
22	Tavern Rock	203 39 37·23	+0·48	37·71

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ± 0″·66.

Patterson, Jefferson County, Missouri. October 24 to October 31, 1873. 28-centimetre theodolite, No. 100. C. H. Boyd and C. H. Van Orden, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
13	Lynch	0 00 00·00	−1·02	58·98
14	Tavern Rock	59 09 22·44	+0·19	22·63
15	Kessler	99 08 36·54	+0·73	37·27
16	Morgan	136 58 17·25	+0·27	17·52
17	Insane Asylum	164 54 00·38	−0·30	00·08
18	Kleinschmidt	185 45 48·89	+0·13	49·02

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ± 0″·79.

Tavern Rock, Franklin County, Missouri. November 12 to November 18, 1873. September 22 to September 25, 1874. 28-centimetre theodolite, No. 100. C. H. Boyd, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″
23	Morgan	0 00 00·00	−0·92	59·08
24	Kessler	11 57 56·76	+0·13	56·89
25	Patterson	52 51 02·39	−0·39	02·00
26	Lynch	99 18 19·48	+0·25	19·73
27	Halleck	148 14 27·66	+0·18	27·84
28	Peters	163 27 28·49	−0·29	28·20
29	Dieckhaus	187 08 25·70	+1·04	26·74

Probable error of a single observation of a direction (6 *D.* and 6 *R.*) = ± 0″·78.

(*b*) *Abstracts of resulting horizontal directions at each station from local and from figure adjustments, 1873–74, 1877–79*—Continued.

Lynch, Jefferson and Franklin counties, Missouri. November 13 to November 17, 1873. September 25 to September 26, 1874. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″
30	Peters	0	00	00·00	−0·33	59·67
31	Halleck	10	08	47·75	−0·52	47·23
32	Dieckhaus	35	19	09·97	−0·21	09·76
33	Tavern Rock	73	31	06·65	−0·18	06·47
34	Patterson	147	54	24·85	+1·24	26·09

Probable error of a single observation of a direction (6 *D*. and 6 *R*.) = ±0″·84.

Halleck, Franklin County, Missouri. September 15 to September 21, 1874. 28-centimetre theodolite, No. 100. C. H. Boyd, observer.

No. of direction.	Objects observed.	°	′	″	″	″
35	Peters	0	00	00·00	−0·19	59·81
36	Enochs Knob	36	28	15·52	−0·08	15·44
37	Dieckhaus	85	11	36·93	+0·09	37·02
38	Tavern Rock	137	29	45·40	−0·19	45·21
39	Lynch	205	11	18·39	+0·37	18·76

Probable error of a single observation of a direction (6 *D*. and 6 *R*.) = ±0″·71.

Dieckhaus, Franklin County, Missouri. September 15 to September 23, 1874. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer.

No. of direction.	Objects observed.	°	′	″	″	″
47	Tavern Rock	0	00	00·00	−1·04	58·96
48	Lynch	53	57	56·33	−0·15	56·18
49	Halleck	88	47	52·54	−0·09	52·45
50	Peters	133	19	06·71	+0·32	07·03
51	Enochs Knob	183	13	45·18	−1·03	44·15
52	Berger	189	10	22·86	+1·99	24·85
	Dutzow Church	194	58	55·15		

Probable error of a single observation of a direction (3 *D*. and 3 *R*.) = ±0″·70.

Peters, Franklin County, Missouri. September 28 to October 2, 1874. 28-centimetre theodolite, No. 100. C. H. Boyd, observer.

No. of direction.	Objects observed.	°	′	″	″	″
40	Jacobs	0	00	00·00	−1·09	58·91
41	Berger	45	53	11·14	+0·20	11·34
42	Enochs Knob	72	07	33·39	−0·36	33·03
43	Dieckhaus	135	08	00·89	+0·06	00·95
44	Tavern Rock	158	07	54·99	−0·11	54·88
45	Halleck	185	25	09·42	+0·14	09·56
46	Lynch	200	27	40·01	+1·17	41·18

Probable error of a single observation of a direction (6 *D*. and 6 *R*.) = ±0″·93.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1873–74, 1878–79*—Continued.

Enochs Knob, Franklin County, Missouri. September 29 to September 30, 1874. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″
53	Dieckhaus	0	00	00·00	−0·29	$\overline{59}$·71
54	Halleck	36	50	47·02	−0·02	47·00
55	Peters	67	04	54·73	+0·51	55·24
56	Jacobs	130	17	33·18	−0·30	32·88
57	Berger	193	12	48·84	+0·10	48·94

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) = ±0″·80.

Berger, Franklin County, Missouri. October 10 to October 13, 1874. 28-centimetre theodolite, No. 106. C. H. Boyd, observer. September 13 to September 19, 1878. 35-centimetre theodolite, No. 10. Telescope above ground 1·62 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	°	′	″	″	″
58	Dieckhaus	0	00	00·00	−0·27	$\overline{59}$·73
59	Enochs Knob	7	16	09·33	−0·95	08·38
60	Peters	34	53	53·96	−0·57	53·39
61	Jacobs	81	38	56·73	+0·27	57·00
	Azimuth Mark	119	30	21·16		
62	Winter	126	52	52·45	+1·16	53·61
63	Gasconade	174	53	30·64	+0·36	31·00

Probable error of a single observation of a direction— (6 *D.* and 6 *R.*) = ±0″·76 in 1874.
(*D.* and *R.*) = ±0·90 in 1878.

Jacobs, Franklin County, Missouri. October 12 to October 15, 1874. 25-centimetre theodolite, No. 74. C. H. Van Orden, observer. September 30 to October 2, 1878. 35-centimetre theodolite, No. 10. Telescope above ground 1·60 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	°	′	″	″	″
65	Gasconade	0	00	00·00	+0·58	00·58
66	Berger	39	12	51·65	−0·83	50·82
67	Enochs Knob	81	54	46·99	−0·23	46·76
68	Peters	126	34	33·93	+1·69	35·62
64	Winter	325	24	03·64	−1·21	02·43

Probable error of a single observation of a direction— (3 *D.* and 3 *R.*) = ±1″·09 in 1874.
(*D.* and *R.*) = ±0·81 in 1878.

(*b*) *Abstracts of resulting horizontal directions at each station from local and from figure adjustments, 1873–74, 1878–79*— Continued.

Gasconade, Gasconade County, Missouri. October 25 to October 31, 1878. 35-centimetre theodolite, No. 10. Telescope above ground 11·73 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
80	Turnpike Bluff	0 00 00·00	±0·11	−0·57	59·43
75	Berger	177 50 43·14	0·12	−1·30	41·84
76	Jacobs	225 23 16·99	0·14	+1·30	18·29
77	Winter	259 20 47·69	0·13	−0·50	47·19
78	Geyer	306 03 46·86	0·20	−0·43	47·29
79	Bradford	354 35 32·74	0·13	−0·64	33·38

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·83.

Winter, Gasconade County, Missouri. October 8 to October 18, 1878. 35-centimetre theodolite, No. 10. Telescope above ground 10·02 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
72	Gasconade	0 00 00·00	±0·12	−0·78	59·22
73	Berger	50 29 16·91	0·17	+0·14	17·05
74	Jacobs	111 26 32·00	0·16	−0·68	32·68
69	Geyer	275 55 49·59	0·16	+0·26	49·85
70	Bradford	302 35 28·81	0·14	−0·57	28·24
71	Turnpike Bluff	330 20 07·78	0·17	−0·27	08·05

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·92.

Geyer, Gasconade County, Missouri. November 18 to November 25, 1878. 35-centimetre theodolite, No. 10. Telescope above ground, 11·40 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
88	Turnpike Bluff	0 00 00·00	±0·12	0·43	59·57
89	Gasconade	29 23 26·55	0·15	+0·10	26·65
90	Winter	78 36 17·82	0·14	−0·09	17·73
86	Pilot Knob	228 51 32·58	0·15	−0·10	32·48
87	Bradford	303 30 39·84	0·12	+0·52	40·36

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·80.

Turnpike Bluff, Gasconade County, Missouri. November 5 to November 13, 1878. 35-centimetre theodolite, No. 10. Telescope above ground 11·34 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
81	Gasconade	0 00 00·00	±0·10	−0·38	59·62
82	Winter	49 40 55·91	0·15	+0·67	56·58
83	Geyer	96 40 21·27	0·13	−0·50	20·77
84	Pilot Knob	125 05 12·98	0·13	+1·07	14·05
85	Bradford	171 38 43·51	0·20	−0·86	42·65

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·85.

(*b*) *Abstracts of resulting horizontal directions at each station from local and from figure adjustments, 1873–74, 1878–79*—Continued.

Bradford, Osage County, Missouri. August 4 to August 12, 1879. 35-centimetre theodolite, No. 10. Telescope above ground 19·81 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
101	McDaniel	0 00 00·00	±0·08	−0·28	59·72
102	Cedar	58 02 56·54	0·18	−0·36	56·18
96	Turnpike Bluff	221 39 28·63	0·16	−0·63	28·00
97	Gasconade	224 36 18·01	0·17	+0·98	18·99
98	Winter	251 57 03·02	0·14	−0·17	02·85
99	Geyer	270 11 47·25	0·17	+0·36	47·61
100	Pilot Knob	324 57 14·44	0·15	+0·10	14·54

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·89.

Pilot Knob, Osage County, Missouri. July 18 to July 22, 1879. 35-centimetre theodolite, No. 10. Telescope above ground 11·31 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
92	McDaniel	0 00 00·00	±0·08	+0·22	00·22
93	Bradford	33 30 15·62	0·13	−0·53	15·09
94	Turnpike Bluff	63 39 00·74	0·14	+0·33	01·07
95	Geyer	84 05 41·55	0·12	−0·19	41·36
	Koeltztown	296 16 50·92	0·39		
91	Kennedy	302 53 20·83	0·10	+0·16	20·99

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·71.

McDaniel, Osage County, Missouri. July 28 to July 31, 1879. 35-centimetre theodolite, No. 10. Telescope above ground 11·09 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
106	Pilot Knob	0 00 00·00	±0·08	−0·40	59·60
	Koeltztown spire	71 36 44·43	0·24		
103	Kennedy	85 42 50·95	0·15	+0·14	51·09
104	Cedar	154 38 47·36	0·12	+0·17	47·53
105	Bradford	248 32 59·00	0·11	+0·09	59·09

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·70.

Cedar, Callaway County, Missouri. August 21 to August 29, 1879. 35-centimetre theodolite, No. 10. Telescope above ground 1·68 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
	Meridian Mark	0 00 00·00	±0·10		
	National Cemetery flagstaff	1 09 25·11	0·37		
115	Belshe	22 20 55·75	0·20	+0·22	55·97
	Capitol	25 52 06·58	0·23		
116	Moreau	51 30 14·21	0·18	−0·94	13·27
117	Medlock	83 29 23·27	0·17	+0·55	23·82
112	Bradford	256 55 56·05	0·16	+0·26	56·31
113	McDaniel	284 58 49·74	0·22	−0·40	49·34
	Koeltztown	323 41 08·77	0·29		
114	Kennedy	331 22 36·39	0·22	+0·31	36·70

Probable error of a single observation of a direction (*D.* and *R.*) = ±1″·06.

(*b*) *Abstracts of resulting horizontal directions at each station from local and from figure adjustments, 1873–74, 1878–79*—Continued.

Medlock, Cole County, Missouri. October 17 to October 21, 1879. 35-centimetre theodolite, No. 10. Telescope above ground 12·59 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
120	Moreau	0	00	00·00	±0·13	−0·23	59·77
121	Christian	54	48	39·70	0·18	+0·37	40·07
118	Cedar	251	24	43·05	0·16	−0·31	42·74
	L'Ours Creek spire	260	38	32·97	0·44		
	Capitol	261	57	34·15	0·28		
119	Belshe	339	39	29·28	0·18	+0·17	29·45

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·00.

Kennedy, Osage County, Missouri. September 4 to September 12, 1879. 35-centimetre theodolite, No. 10. Telescope above ground 11·28 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
	Koeltztown, Roman Catholic Church spire	0	00	00·00	±0·12		
107	Belshe	156	09	33·56	0·16	+0·54	34·10
108	Moreau	184	39	38·44	0·22	−0·57	37·87
109	Cedar	231	29	46·19	0·18	+0·08	46·27
	L'Ours Creek spire	275	57	14·86	0·18		
110	McDaniel	296	10	04·19	0·18	−0·31	03·88
111	Pilot Knob	333	20	33·77	0·21	−0·26	34·03

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·06.

Moreau, Cole County, Missouri. October 7 to October 11, 1879. 35-centimetre theodolite, No. 10. Telescope above ground 19·87 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
127	High Point	0	00	00·00	±0·11	+0·87	00·87
	Cole	40	19	35·30	0·18		
	California spire	59	31	26·40	0·27		
122	Christian	61	55	12·27	0·17	−0·94	11·33
123	Medlock	137	37	10·81	0·21	+0·28	11·09
124	Cedar	177	02	43·82	0·20	−0·29	44·11
125	Kennedy	230	05	01·07	0·15	−0·10	00·97
126	Belshe	280	05	50·46	0·17	−0·40	50·06

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·00.

(b) Abstracts of resulting horizontal directions of each station from local and from figure adjustments—Continued.

Christian, Moniteau County, Missouri. October 25 to November 7, 1879. 35-centimetre theodolite, No. 10. Telescope above ground 12·28 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	High Point	0	00	00·00	±0·09	+0·40		00·40
	Hunter (Versailles South Base)	30	12	30·25	0·21	−0·68		29·57
	Versailles North Base	44	54	30·92	0·18	−0·37		30·55
	Hughes	45	29	22·83	0·22	−0·29		22·54
	Cole	81	30	23·13	0·18	+0·70		23·83
	Tipton, Baptist Church spire	87	02	15·50	0·22			
	Hubbard	89	08	40·05	0·16	−0·21		39·84
	California, Christian Church spire	100	45	10·25	0·38			
128	Medlock	254	50	12·26	0·20		−0·13	12·13
129	Moreau	304	19	34·86	0·17		−2·24	32·62
	Belshe	324	18	41·00	0·17	+0·45		41·45
					Mean	0·00		

Probable error of a single observation of a direction (*D*. and *R*.) = ± 1″·04.

High Point, Moniteau County, Missouri. July 10 to July 17, 1880. 35-centimetre theodolite, No. 10. Telescope above ground 9·69 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Christian	0	00	00·00	±0·11	−0·51		59·49
130	Moreau	62	24	21·31	0·17		+0·44	21·75
	Belshe	117	56	13·80	0·18	−0·35		13·45
	Hunter (Versailles South Base)	235	44	00·73	0·16	+0·45		01·18
	Versailles North Base	258	50	31·60	0·21	+0·65		32·25
	Hubbard	298	10	34·62	0·15	−0·92		33·70
	Tipton, First Baptist Church spire	305	18	53·98	0·15			
	Cole	310	03	36·27	0·19	+0·67		36·94
	California, Christian Church spire	353	37	15·09	0·29			
					Mean	0·00		

Probable error of a single observation of a direction (*D*. and *R*.) = ± 0″·99.

(*b*) *Abstracts of resulting horizontal directions of each station from local and from figure adjustments*—Continued.

Belshe, Cole County, Missouri. September 20 to October 1, 1879. 35-centimetre theodolite, No. 10. Telescope above ground 9·75 metres. H. W. Blair, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
131	Moreau	0	00	00·90	±0·09		−2·45	57·55
132	Medlock	17	10	49·00	0·16		−0·37	48·63
133	Cedar	47	47	35·48	0·19		−0·09	35·39
	St. Thomas spire	98	47	48·10	0·31			
134	Kennedy	101	29	05·71	0·18		+0·11	05·82
	Koeltztown spire	105	24	14·06	0·25			
	Hunter (Versailles South Base)	286	21	33·83	0·20	+0·18		34·01
	Versailles North Base	296	16	08·69	0·15	+0·01		08·70
	High Point	315	25	60·07	0·18	−0·62		59·45
	California spire	339	35	39·60	0·38			
	Christian	341	48	26·80	0·18	+0·44		27·24
					Mean	0·00		

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 1''\!\cdot\!10$.

(*c*) *Figure adjustment.*

Observation equations.

No.	
1	$0 = +3.48 + (1) - (6) - (7) + (8)$
2	$0 = +0.43 - (3) + (6) - (8) + (9)$
3	$0 = +0.76 - (2) + (4) - (17) + (18)$
4	$0 = -1.34 - (2) + (3) - (9) + (10) - (16) + (18)$
5	$0 = -0.30 - (10) + (11) - (15) + (16) - (19) + (21)$
6	$0 = +1.48 - (4) + (5) - (15) + (17) - (20) + (21)$
7	$0 = -0.14 - (10) + (12) - (14) + (16) - (23) + (25)$
8	$0 = +1.16 - (11) + (12) + (19) - (22) - (23) + (24)$
9	$0 = -3.27 - (13) + (14) - (25) + (26) - (33) + (34)$
10	$0 = -0.83 - (26) + (27) - (31) + (33) - (38) + (39)$
11	$0 = -1.71 - (26) + (29) - (32) + (33) - (47) + (48)$
12	$0 = -1.52 - (27) + (29) - (37) + (38) - (47) + (49)$
13	$0 = -1.70 - (30) + (32) - (43) + (46) - (48) + (50)$
14	$0 = -0.29 - (30) + (31) + (35) - (39) - (45) + (46)$
15	$0 = -2.52 - (28) + (29) - (43) + (44) - (47) + (50)$
16	$0 = +0.50 - (36) + (37) - (49) + (51) - (53) + (54)$
17	$0 = -1.85 - (40) + (42) - (55) + (56) - (67) + (68)$
18	$0 = -2.20 - (56) + (57) - (59) + (61) - (66) + (67)$
19	$0 = -4.64 - (40) + (41) - (60) + (61) - (66) + (68)$
20	$0 = -1.24 - (41) + (43) - (50) + (52) - (58) + (60)$

(*c*) *Figure adjustment*—Continued.

Observation equations—Continued.

No.	
21	$0 = -1.96 - (51) + (52) + (53) - (57) - (58) + (59)$
22	$0 = -1.82 - (61) + (62) - (64) + (66) - (73) + (74)$
23	$0 = -1.29 - (61) + (63) - (65) + (66) - (75) + (76)$
24	$0 = -0.92 - (62) + (63) - (72) + (73) - (75) + (77)$
25	$0 = +0.08 - (71) + (72) - (77) + (80) - (81) + (82)$
26	$0 = +0.31 - (69) + (72) - (77) + (78) - (89) + (90)$
27	$0 = +0.81 - (69) + (71) - (82) + (83) - (88) + (90)$
28	$0 = +0.23 - (70) + (71) - (82) + (85) - (96) + (98)$
29	$0 = -0.087 - (79) + (80) - (81) + (85) - (96) + (97)$
30	$0 = -0.70 - (86) + (87) - (93) + (95) - (99) + (100)$
31	$0 = +0.35 - (84) - (85) - (93) + (94) - (96) + (100)$
32	$0 = -0.72 - (83) + (84) - (86) + (88) - (94) + (95)$
33	$0 = +1.62 - (92) + (93) - (100) + (101) - (105) + (106)$
34	$0 = -1.17 - (91) + (92) + (103) - (106) - (110) + (111)$
35	$0 = +0.82 - (101) + (102) - (104) + (105) - (112) + (113)$
36	$0 = -0.36 - (103) + (104) - (109) + (110) - (113) + (114)$
37	$0 = +0.33 - (107) + (109) - (114) + (115) - (133) + (134)$
38	$0 = +1.00 - (108) + (109) - (114) + (116) - (124) + (125)$
39	$0 = -1.17 - (107) + (108) - (131) + (134) - (125) + (126)$
40	$0 = -1.07 - (115) + (117) - (118) - (119) - (132) + (133)$
41	$0 = -1.58 - (116) + (117) - (123) - (124) - (118) + (120)$
42	$0 = -0.03 - (128) + (132) - (119) + (121)$
43	$0 = -0.87 + (122) - (127) - (129) + (130)$
44	$0 = +1.62 - (126) + (127) - (130) - (131)$
45	$0 = -1.37 - 0.61(1) + 2.60(3) + 1.61(7) - 4.64(8) + 3.03(9)$
46	$0 = -0.5 - 3.00(4) - 0.61(6) - 3.03(8) - 5.06(9) + 2.03(10) - 1.84(16) - 5.52(17) + 3.68(18)$
47	$0 = -5.0 - 2.87(4) + 5.89(5) - 3.02(6) - 1.15(8) - 2.73(10) - 3.88(11) - 1.76(15) + 2.71(16) - 0.95(17)$
48	$0 = -30.9 - 2.73(10) + 12.91(11) - 10.18(12) - 2.51(14) - 5.22(15) - 2.71(16) - 9.93(23) + 12.37(24) - 2.44(25)$
49	$0 = -1.5 + 1.83(26) - 4.44(27) + 2.61(29) - 3.43(31) - 4.48(32) + 1.05(33) - 0.04(47) - 3.03(48) + 2.99(49)$
50	$0 = -7.6 + 5.13(27) - 7.74(28) + 2.61(29) - 1.75(43) - 4.09(44) - 2.34(45) - 0.04(47) - 2.18(49) + 2.14(50)$
51	$0 = -12.2 + 11.77(30) - 16.25(31) + 4.48(32) + 1.75(43) - 9.58(45) + 7.83(46) + 3.03(48) - 5.17(49) + 2.14(50)$
52	$0 = +2.3 + 2.67(35) - 2.85(36) - 0.18(37) + 2.14(49) - 3.91(50) - 1.77(51) + 0.89(53) - 3.62(54) + 2.73(55)$
53	$0 = +78.9 - 4.27(41) + 5.35(42) - 1.08(43) - 1.77(50) + 21.99(51) - 20.22(52) - 16.51(58) + 20.53(59) - 4.02(60)$
54	$0 = -1.0 - 0.68(40) + 4.27(41) - 3.59(42) - 3.43(59) + 4.02(60) - 0.59(61) - 2.29(66) + 4.42(67) - 2.13(68)$

(*c*) *Figure adjustment*—Continued.

Observation equations—Continued.

No.

55 0 = + 14·5 + 2·09 (61) − 3·99 (62) + 1·90 (63) + 2·44 (64) − 3·05 (65) + 0·61 (66) − 3·13 (76)
+ 2·82 (77) + 0·31 (75)

56 0 = − 7·3 − 1·51 (69) + 5·21 (71) − 3·70 (72) + 0·40 (77) + 1·53 (78) − 1·93 (80) − 3·31 (88)
+ 3·73 (89) − 0·42 (90)

57 0 = + 5·0 − 1·51 (69) + 4·01 (70) − 2·50 (71) − 1·40 (87) + 1·82 (88) − 0·42 (90) − 1·75 (96)
+ 3·61 (98) − 1·86 (99)

58 0 = − 85·7 − 1·53 (78) + 22·25 (79) + 20·72 (80) − 1·40 (87) + 5·13 (88) − 3·73 (89) − 39·04 (96)
+ 40·90 (97) − 1·86 (99)

59 0 = + 12·0 + 3·32 (83) − 3·89 (84) + 0·57 (85) − 5·65 (94) + 3·92 (95) + 1·73 (93) + 1·86 (96)
− 3·35 (99) + 1·49 (100)

60 0 = + 4·6 − 1·36 (91) + 4·54 (92) − 3·18 (93) − 3·00 (100) + 4·32 (101) − 1·32 (102) − 1·00 (109)
+ 3·77 (110) − 2·77 (111) − 3·95 (112) + 5·96 (113) − 2·01 (114)

61 0 = + 1·1 + 3·33 (107) − 3·88 (108) + 0·55 (109) + 1·71 (114) − 5·49 (115) + 3·78 (116)
− 0·49 (124) − 1·77 (125) + 2·26 (126)

62 0 = + 2·4 + 3·78 (115) − 7·15 (116) + 3·37 (117) − 0·70 (118) − 5·68 (119) − 6·38 (120)
− 4·90 (131) − 6·81 (132) + 1·91 (133)

63 0 = + 26·0 − 3·78 (115) + 7·15 (116) − 3·37 (117) + 0·70 (118) + 0·79 (120) − 1·49 (121)
− 1·80 (128) + 3·24 (129) + 2·55 (130) + 4·05 (131) − 1·91 (133)

64 0 = − 21·3 − 4·35 (129) + 2·55 (130) − 4·26 (131)

65 0 = + 6·6 − 0·18 (2) + 0·18 (3) − 0·61 (6) + 3·03 (8) − 3·03 (9) − 1·81 (10) + 1·81 (12) − 1·26 (13)
+ 1·26 (14) + 1·84 (16) − 1·84 (18) + 1·60 (23) − 1·60 (25) − 0·08 (26) + 0·08 (29) − 2·97 (30)
+ 2·97 (32) + 0·59 (33) − 0·59 (34) + 2·04 (40) − 2·04 (41) + 0·97 (43) − 0·97 (46) + 1·54 (47)
− 1·54 (48) − 1·43 (50) + 1·43 (52) + 3·02 (58) − 3·02 (60) − 1·90 (62) + 1·90 (63) − 0·61 (64)
+ 0·71 (66) − 0·10 (68) − 0·21 (69) + 0·21 (72) + 1·17 (73) − 1·17 (74) + 0·31 (75) − 0·31 (77)
− 1·86 (78) + 1·86 (79) − 0·58 (86) + 0·58 (87) + 1·82 (89) − 1·82 (90) − 1·36 (91) + 1·36 (92)
+ 1·73 (93) − 1·73 (95) + 2·07 (97) − 2·07 (99) − 3·00 (100) + 3·00 (101) − 0·81 (103)
+ 0·81 (104) − 0·83 (105) + 0·83 (106) − 0·55 (107) + 0·55 (109) + 2·77 (110) − 2·77 (111)
+ 2·01 (113) − 2·01 (114) − 1·17 (115) + 1·17 (117) + 0·07 (118) − 0·63 (119) + 0·56 (121)
+ 0·79 (128) + 1·55 (133) − 1·55 (134)

Correlate equations.

$(1) = -C_1 - 0{\cdot}61C_{45}$

$(2) = -C_3 - C_4 - 0{\cdot}18C_{65}$

$(3) = -C_2 + C_4 + 2{\cdot}60C_{45} + 0{\cdot}18C_{65}$

$(4) = +C_3 - C_6 - 3{\cdot}00C_{46} - 2{\cdot}87C_{47}$

$(5) = +C_6 + 5{\cdot}89C_{47}$

$(6) = -C_1 + C_2 - 0{\cdot}61C_{46} + 3{\cdot}02C_{47} + 0{\cdot}61C_{65}$

$(7) = -C_1 + 1{\cdot}61C_{45}$

$(8) = +C_1 - C_2 - 4{\cdot}64C_{45} - 3{\cdot}03C_{46} + 1{\cdot}15C_{47} + 3{\cdot}03C_{65}$

$(9) = +C_2 - C_4 + 3{\cdot}03C_{45} - 5{\cdot}06C_{46} + 3{\cdot}03C_{65}$

$(10) = +C_4 - C_5 - C_7 - 2{\cdot}03C_{46} + 2{\cdot}73C_{47} - 2{\cdot}73C_{48} - 1{\cdot}81C_{65}$

$(11) = +C_5 - C_8 - 3{\cdot}88C_{47} + 12{\cdot}91C_{48}$

$(12) = +C_7 + C_8 - 10{\cdot}18C_{48} + 1{\cdot}81C_{65}$

$(13) = -C_9 - 1{\cdot}26C_{65}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

$(14) = -C_7 + C_9 - 2.51C_{48} + 1.26C_{65}$

$(15) = -C_5 - C_6 - 1.76C_{47} + 5.22C_{48}$

$(16) = -C_4 + C_5 + C_7 + 1.84C_{46} + 2.71C_{47} - 2.71C_{48} + 1.84C_{65}$

$(17) = -C_3 + C_6 - 5.52C_{46} - 0.95C_{47}$

$(18) = +C_3 + C_4 + 3.68C_{46} - 1.84C_{65}$

$(19) = -C_5 + C_8$

$(20) = -C_6$

$(21) = +C_5 + C_6$

$(22) = -C_8$

$(23) = -C_7 - C_8 - 9.93C_{48} + 1.60C_{65}$

$(24) = +C_8 + 12.37C_{48}$

$(25) = +C_7 - C_9 - 2.44C_{48} - 1.60C_{65}$

$(26) = +C_9 - C_{10} - C_{11} + 1.83C_{49} - 0.08C_{65}$

$(27) = +C_{10} - C_{12} - 4.44C_{49} + 5.13C_{50}$

$(28) = -C_{15} - 7.74C_{50}$

$(29) = +C_{11} + C_{12} + C_{15} + 2.61C_{49} + 2.61C_{50} + 0.08C_{65}$

$(30) = -C_{13} - C_{14} + 11.77C_{51} - 2.97C_{65}$

$(31) = -C_{10} + C_{14} + 3.43C_{49} - 16.25C_{51}$

$(32) = -C_{11} + C_{13} - 4.48C_{49} + 4.48C_{51} + 2.97C_{65}$

$(33) = -C_9 + C_{10} + C_{11} + 1.05C_{49} + 0.59C_{65}$

$(34) = +C_9 - 0.59C_{65}$

$(35) = +C_{14} + 2.67C_{52}$

$(36) = -C_{16} - 2.85C_{52}$

$(37) = -C_{12} + C_{16} + 0.18C_{52}$

$(38) = -C_{10} + C_{12}$

$(39) = +C_{10} - C_{14}$

$(40) = -C_{17} - C_{19} - 0.68C_{54} - 2.04C_{65}$

$(41) = +C_{19} - C_{20} - 4.27C_{53} + 4.27C_{54} + 2.04C_{65}$

$(42) = +C_{17} + 5.35C_{53} - 3.59C_{54}$

$(43) = -C_{13} - C_{15} + C_{20} + 1.75C_{50} + 1.75C_{51} - 1.08C_{53} + 0.97C_{65}$

$(44) = +C_{15} - 4.09C_{50}$

$(45) = -C_{14} + 2.34C_{50} - 9.58C_{51}$

$(46) = +C_{13} + C_{14} + 7.83C_{51} - 0.97C_{65}$

$(47) = -C_{11} - C_{12} - C_{15} + 0.04C_{49} + 0.04C_{50} + 1.54C_{65}$

$(48) = +C_{11} - C_{13} - 3.03C_{49} + 3.03C_{51} - 1.54C_{65}$

$(49) = +C_{12} - C_{16} + 2.99C_{49} - 2.18C_{50} - 5.17C_{51} + 2.14C_{52}$

$(50) = +C_{13} + C_{15} - C_{20} + 2.14C_{50} + 2.14C_{51} - 3.91C_{52} - 1.77C_{53} - 1.43C_{65}$

$(51) = +C_{16} - C_{21} + 1.77C_{52} + 21.99C_{53}$

$(52) = +C_{20} + C_{21} - 20.22C_{53} + 1.43C_{65}$

$(53) = -C_{16} + C_{21} + 0.89C_{52}$

$(54) = +C_{16} - 3.62C_{52}$

$(55) = -C_{17} + 2.73C_{52}$

$(56) = +C_{17} - C_{18}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

$(57) = +C_{18} - C_{21}$

$(58) = -C_{20} - C_{21} - 16\cdot51C_{53} + 3\cdot02C_{65}$

$(59) = -C_{18} + C_{21} + 20\cdot53C_{53} - 3\cdot43C_{54}$

$(60) = -C_{19} + C_{20} - 4\cdot02C_{53} + 4\cdot02C_{54} - 3\cdot02C_{65}$

$(61) = +C_{18} + C_{19} - C_{22} - C_{23} - 0\cdot59C_{54} + 2\cdot09C_{55}$

$(62) = +C_{22} - C_{24} - 3\cdot99C_{55} - 1\cdot90C_{65}$

$(63) = +C_{23} + C_{24} + 1\cdot90C_{55} + 1\cdot90C_{65}$

$(64) = -C_{22} + 2\cdot44C_{55} - 0\cdot61C_{65}$

$(65) = -C_{23} - 3\cdot05C_{55}$

$(66) = -C_{18} - C_{19} + C_{22} + C_{23} - 2\cdot29C_{54} + 0\cdot61C_{55} + 0\cdot71C_{65}$

$(67) = -C_{17} + C_{18} + 4\cdot42C_{54}$

$(68) = +C_{17} + C_{19} - 2\cdot13C_{54} - 0\cdot10C_{65}$

$(69) = -C_{26} - C_{27} - 1\cdot51C_{56} - 1\cdot51C_{57} - 0\cdot21C_{65}$

$(70) = -C_{28} + 4\cdot01C_{57}$

$(71) = -C_{25} + C_{27} + C_{28} + 5\cdot21C_{56} - 2\cdot50C_{57}$

$(72) = -C_{24} + C_{25} + C_{26} - 3\cdot70C_{56} + 0\cdot21C_{65}$

$(73) = -C_{22} + C_{24} + 1\cdot17C_{65}$

$(74) = +C_{22} - 1\cdot17C_{65}$

$(75) = -C_{23} - C_{24} + 0\cdot31C_{55} + 0\cdot31C_{65}$

$(76) = +C_{23} - 3\cdot13C_{55}$

$(77) = +C_{24} - C_{25} - C_{26} + 2\cdot82C_{55} + 0\cdot40C_{56} - 0\cdot31C_{65}$

$(78) = +C_{26} + 1\cdot53C_{56} - 1\cdot53C_{58} - 1\cdot86C_{65}$

$(79) = -C_{29} + 22\cdot25C_{58} + 1\cdot86C_{65}$

$(80) = +C_{25} + C_{29} - 1\cdot93C_{56} - 20\cdot72C_{58}$

$(81) = -C_{25} - C_{29}$

$(82) = +C_{25} - C_{27} - C_{28}$

$(83) = +C_{27} - C_{32} + 3\cdot32C_{59}$

$(84) = -C_{31} + C_{32} - 3\cdot89C_{59}$

$(85) = +C_{28} + C_{27} + C_{31} + 0\cdot57C_{59}$

$(86) = -C_{30} - C_{32} - 0\cdot58C_{65}$

$(87) = +C_{30} - 1\cdot40C_{57} - 1\cdot40C_{58} + 0\cdot58C_{65}$

$(88) = -C_{27} + C_{32} - 3\cdot31C_{56} + 1\cdot82C_{57} + 5\cdot13C_{58}$

$(89) = -C_{26} + 3\cdot73C_{56} - 3\cdot73C_{58} + 1\cdot82C_{65}$

$(90) = +C_{26} + C_{27} - 0\cdot42C_{56} - 0\cdot42C_{57} - 1\cdot82C_{65}$

$(91) = -C_{34} - 1\cdot36C_{60} - 1\cdot36C_{65}$

$(92) = -C_{33} + C_{34} + 4\cdot54C_{60} + 1\cdot36C_{65}$

$(93) = -C_{30} - C_{31} + C_{33} + 1\cdot73C_{59} - 3\cdot18C_{60} + 1\cdot73C_{65}$

$(94) = +C_{31} - C_{32} - 5\cdot65C_{59}$

$(95) = +C_{30} + C_{32} + 3\cdot92C_{59} - 1\cdot73C_{65}$

$(96) = -C_{28} - C_{29} - C_{31} - 1\cdot75C_{57} - 39\cdot04C_{58} + 1\cdot86C_{59}$

$(97) = +C_{29} + 40\cdot90C_{58} + 2\cdot07C_{65}$

$(98) = +C_{28} + 3\cdot61C_{57}$

$(99) = -C_{30} - 1\cdot86C_{57} - 1\cdot86C_{58} - 3\cdot35C_{59} - 2\cdot07C_{65}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Completed.

$(100) = + C_{30} + C_{31} - C_{33} + 1{\cdot}49C_{59} - 3{\cdot}00C_{60} - 3{\cdot}00C_{65}$
$(101) = + C_{33} - C_{35} + 4{\cdot}32C_{60} + 3{\cdot}00C_{65}$
$(102) = + C_{35} - 1{\cdot}32C_{60}$
$(103) = + C_{34} - C_{36} - 0{\cdot}81C_{65}$
$(104) = - C_{35} + C_{36} + 0{\cdot}81C_{65}$
$(105) = - C_{33} + C_{35} - 0{\cdot}83C_{65}$
$(106) = + C_{33} - C_{34} + 0{\cdot}83C_{65}$
$(107) = - C_{37} - C_{39} + 3{\cdot}33C_{61} - 0{\cdot}55C_{65}$
$(108) = - C_{38} + C_{39} - 3{\cdot}88C_{61}$
$(109) = - C_{36} + C_{37} + C_{38} - 1{\cdot}00C_{60} + 0{\cdot}55C_{61} + 0{\cdot}55C_{65}$
$(110) = - C_{34} + C_{36} + 3{\cdot}77C_{60} + 2{\cdot}77C_{65}$
$(111) = + C_{34} - 2{\cdot}77C_{60} - 2{\cdot}77C_{65}$
$(112) = - C_{35} - 3{\cdot}95C_{60}$
$(113) = + C_{35} - C_{36} + 5{\cdot}96C_{60} + 2{\cdot}01C_{65}$
$(114) = + C_{36} - C_{37} - C_{38} - 2{\cdot}01C_{60} + 1{\cdot}71C_{61} - 2{\cdot}01C_{65}$
$(115) = + C_{37} - C_{40} - 5{\cdot}49C_{61} + 3{\cdot}78C_{62} - 3{\cdot}78C_{63} - 1{\cdot}17C_{65}$
$(116) = + C_{38} - C_{41} + 3{\cdot}78C_{61} - 7{\cdot}15C_{62} + 7{\cdot}15C_{63}$
$(117) = + C_{40} + C_{41} + 3{\cdot}37C_{62} - 3{\cdot}37C_{63} + 1{\cdot}17C_{65}$
$(118) = - C_{40} - C_{41} - 0{\cdot}70C_{62} + 0{\cdot}70C_{63} + 0{\cdot}07C_{65}$
$(119) = + C_{40} - C_{42} - 5{\cdot}68C_{62} - 0{\cdot}63C_{65}$
$(120) = + C_{41} + 6{\cdot}38C_{62} + 0{\cdot}79C_{63}$
$(121) = + C_{42} - 1{\cdot}49C_{63} + 0{\cdot}56C_{65}$
$(122) = + C_{43}$
$(123) = - C_{41}$
$(124) = - C_{38} + C_{41} - 0{\cdot}49C_{61}$
$(125) = + C_{38} - C_{39} - 1{\cdot}77C_{61}$
$(126) = + C_{39} - C_{44} + 2{\cdot}26C_{61}$
$(127) = - C_{43} + C_{44}$
$(128) = - C_{42} - 1{\cdot}80C_{63} + 0{\cdot}79C_{65}$
$(129) = - C_{43} + 3{\cdot}24C_{63} - 4{\cdot}35C_{64}$
$(130) = + C_{43} - C_{44} + 2{\cdot}55C_{63} + 2{\cdot}55C_{64}$
$(131) = - C_{39} + C_{44} + 4{\cdot}90C_{62} + 4{\cdot}05C_{63} - 4{\cdot}26C_{64}$
$(132) = - C_{40} + C_{42} - 6{\cdot}81C_{62}$
$(133) = - C_{37} + C_{40} + 1{\cdot}91C_{62} - 1{\cdot}91C_{63} + 1{\cdot}55C_{65}$
$(134) = + C_{37} + C_{39} - 1{\cdot}55C_{65}$

(*c*) *Figure adjustment*—Continued.

Normal equations.

		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
1	0 = +3·48	+4	−2												
2	+0·43		+4		−2										
3	+0·76			+4	+2		−2								
4	−1·34				+6	−2		−2							
5	−0·30	...	...	...	...	+6	+2	+2	−2	...	...	...	...	...	...
6	+1·48						+6								
7	−0·14							+6	+2	−2					
8	+1·16								+6						
9	−3·27									+6	−2	−2			
10	−0·83	...	...	...	...	...	...	...	...	...	+6	+2	−2	...	−2
11	−1·71											+6	+2	−2	
12	−1·52												+6		
13	−1·70													+6	+2
14	−0·29														+6

Normal equations—Continued.

		C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}
11	0 = −1·71	+2													
12	−1·52	+2	−2												
13	−1·70	+2					−2								
15	−2·52	+6					−2								
16	+0·50	...	+6	...	...	...	...	−2	...	...	...	...	...	...	...
17	−1·85			+6	−2	+2									
18	−2·20				+6	+2		−2	−2	−2					
19	−4·64					+6	−2		−2	−2					
20	−1·24						+6	+2							
21	−1·96	...	...	...	...	...	...	+6	...	...	...	...	...	...	...
22	−1·82								+6	+2	−2				
23	−1·29									+6	+2				
24	−0·92										+6	−2	−2		
25	+0·08											+6	+2	−2	−2
26	+0·31	...	...	...	...	...	...	...	...	...	...	...	+6	+2	
27	+0·81													+6	+2
28	+0·23														+6

(*c*) *Figure adjustment*—Continued.

Normal equations—Continued.

		C_{29}	C_{30}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{39}	C_{40}	C_{41}	C_{42}	C_{43}	C_{44}
25	0=+0.08	+2															
27	+0.81				−2												
28	+0.23	+2		+2													
29	+0.087	+6		+2													
30	−0.70	...	+6	+2	−2	−2	...	...	...	...	...	...	...	...	...	...	...
31	+0.35			+6	−2	−2											
32	−0.72				+6												
33	+1.62					+6	−2	−2									
34	−1.17						+6		−2								
35	+0.82	...	...	...	...	...	...	+6	−2	...	...	...	...	...	...	...	...
36	−0.36								+6	−2	−2						
37	+0.33									+6	+2	+2	−2				
38	+1.00										+6	−2		−2			
39	−1.17											+6					−2
40	−1.07	...	...	...	...	...	...	...	...	...	...	...	+6	+2	−2	...	...
41	−1.58													+6			
42	+0.03														+4		
43	−0.87															+4	−2
44	+1.62																+4

Normal equations—Continued.

		C_{45}	C_{46}	C_{47}	C_{48}	C_{49}	C_{50}	C_{51}
1	0=+3.48	− 5.64	+3.64	+4.17				
2	+ 0.43	+ 5.07	−8.70	−4.17				
3	+ 0.76		+6.20	−1.92				
4	− 1.34	− 0.43	+8.93	+0.02	−0.02			
5	− 0.30	....	−0.19	−2.14	+7.71	....	....	....
6	+ 1.48		−2.52	+9.57	−5.22			
7	− 0.14		−0.19	−0.02	−0.16			
8	+ 1.16			+3.88	−0.79			
9	− 3.27				−0.07	+ 0.78		
10	− 0.83		....	....	....	− 8.65	+5.13	+16.25
11	− 1.71					+ 3.24	+2.57	− 1.45
12	− 1.52					+10.00	−4.74	− 5.17
13	− 1.70					− 1.45	+0.39	− 2.10
14	− 0.29					+ 3.43	−2.34	−10.61
15	− 2.52	....	....	....	....	+ 2.57	+6.61	+ 0.39
16	+ 0.50					− 2.99	+2.18	+ 5.17
20	− 1.24						−0.39	− 0.39
45	−13.7	+40.435	−29.391	− 5.34				

(*c*) *Figure adjustment*—Continued.

Normal equations—Continued.

		C_{45}	C_{46}	C_{47}	C_{48}	C_{49}	C_{50}	C_{51}
46	− 0·5		+95·676	+29·71	− 10·53			
47	+ 5·0	....	....	+87·22	− 74·08	....	....	....
48	−30·9				+576·22			
49	− 1·5					+80·94	− 22·48	−100·45
50	− 7·6						+127·64	− 3·50
51	−12·2							+619·30

Normal equations—Continued.

		C_{52}	C_{53}	C_{54}	C_{55}	C_{56}	C_{57}	C_{58}
12	0=− 1·52	+1·96						
13	− 1·70	−3·91	− 0·69					
14	− 0·29	+2·67						
15	− 2·52	−3·91	− 0·69					
16	+ 0·50	−1·85	+21·99	....	....	....	....	....
17	− 1·85	−2·73	+ 5·35	−9·46				
18	− 2·20		−20·53	+9·55	+1·48			
19	− 4·64		− 0·25	+0·50	+1·48			
20	− 1·24	+3·91	− 2·77	−0·25				
21	− 1·96	−0·88	− 5·17	−3·43	....	....	....	....
22	− 1·82			−1·70	−7·91			
23	− 1·29			−1·70	+0·03			
24	− 0·92				+8·40	+4·10		
25	+ 0·08				−2·82	−11·24	+2·50	−20·72
26	+ 0·31	....	....	....	−2·82	− 5·21	+1·09	+ 2·20
27	+ 0·81					+ 9·61	−3·23	− 5·13
28	+ 0·23					+ 5·21	−1·15	+39·04
29	+ 0·087					− 1·93	+1·75	+36·97
30	− 0·70						+0·46	+ 0·46
31	+ 0·35	....	....	....	....	....	+1·75	+39·04
32	− 0·72					− 3·31	+1·82	+ 5·13
49	− 1·5	+ 6·40						
50	− 7·6	−13·03	− 5·68					
51	−12·2	−19·43	− 5·68					
52	+ 2·3	+59·63	+45·84	....	....	....	....	....
53	+78·9		+1 653·78	−124·02				
54	− 1·0			+ 89·17	− 2·63			
55	+14·5				+57·37	+ 1·13		
56	− 7·3					+74·39	−16·59	+ 6·76
57	+ 5·0	....	....	....	....	....	+49·61	+83·08
58	−85·7							+4 169·30

(*c*) *Figure adjustment*—Continued.

Normal equations—Continued.

		C_{59}	C_{60}	C_{61}	C_{62}	C_{63}	C_{64}	C_{65}
1	0=+ 3.48							+3.64
2	+ 0.43							−6.85
3	+ 0.76							−1.66
4	− 1.34							−2.10
5	− 0.30	....	....	....	....	....	....	+3.65
7	− 0.14							+1.00
8	+ 1.16							+0.21
9	− 3.27							+2.86
10	− 0.83							+0.67
11	− 1.71	....	....	....	....	....	....	−5.30
12	− 1.52							−1.46
13	− 1.70							+4.11
14	− 0.29							+2.00
15	− 2.52							−3.86
17	− 1.85	....	....	....	....	....	....	+1.94
18	− 2.20							−0.71
19	− 4.64							+6.29
20	− 1.24							−4.25
21	− 1.96							−1.59
22	− 1.82	....	....	....	....	....	....	−2.92
23	− 1.29							+2.30
24	− 0.92							+4.14
25	+ 0.08							+0.52
26	+ 0.31							−4.77
27	+ 0.81	+3.32	....	....	....	....	....	−1.61
28	+ 0.23	−1.29						
29	+ 0.087	−1.29						+0.21
30	− 0.70	+ 7.03	+0.18					−3.23
31	+ 0.35	−3.29	+0.18					−4.73
32	− 0.72	+2.36	....	....	....	....	....	−1.15
33	+ 1.62	+0.24	−0.40					+8.03
34	− 1.17		−0.64					−4.46
35	+ 0.82		+4.27					−2.63
36	− 0.36		−3.20	+1.16				−0.18
37	+ 0.33	....	+1.01	−9.98	+ 1.87	− 1.87	....	−1.16
38	+ 1.00		+1.01	+5.22	− 7.15	+ 7.15		+2.56
39	− 1.17			−3.18	− 4.90	− 4.05	+4.26	−1.00
40	− 1.07			+5.49	+ 3.33	− 2.20		+3.19
41	− 1.58			−4.27	+17.60	−10.43		+1.10
42	+ 0.03	....	....	....	− 1.13	+ 0.31	....	+0.40
43	− 0.87					− 0.69	+6.90	

(*c*) *Figure adjustment*—Completed.

Normal equations—Completed.

		C_{59}	C_{60}	C_{61}	C_{62}	C_{63}	C_{64}	C_{65}
44	0=+ 1·62			−2·26	+ 4·90	+ 1·50	−6·81	
45	−13·7							− 22·77
46	− 0·5							+ 17·825
47	+ 5·0	....	....	....	....	....	....	+ 5·37
48	−30·9							− 33·62
49	− 1·5							− 7·90
50	− 7·6							− 1·09
51	−12·2							− 35·28
52	+ 2·3	....	....	....	....	....	....	+ 5·59
53	+78·9							− 73·86
54	− 1·0							− 3·46
55	+14·5							+ 9·36
56	− 7·3							+ 4·12
57	+ 5·0	+ 2·98	....	....	....	....	....	+ 4·12
58	−85·7	−66·38						+125·14
59	+12·0	+93·66	− 9·97					− 1·32
60	+ 4·6		+140·03	− 3·99				+ 58·07
61	+ 1·1			+82·28	− 47·78	+ 47·78		+ 1·46
62	+ 2·4	....	....	....	+224·26	− 56·02	−20·87	+ 6·01
63	+26·0					+120·39	−24·84	− 4·69
64	−21·3						+43·57	
65	+ 6·6							+193·25

Resulting values of correlates.

$C_{1}=-0{\cdot}790$	$C_{18}=-0{\cdot}169$	$C_{35}=-0{\cdot}334$	$C_{52}=+0{\cdot}015\ 7$
$C_{2}=-0{\cdot}782$	$C_{19}=+1{\cdot}886$	$C_{36}=-0{\cdot}065$	$C_{53}=-0{\cdot}061\ 5$
$C_{3}=-0{\cdot}693$	$C_{20}=+1{\cdot}188$	$C_{37}=+0{\cdot}657$	$C_{54}=-0{\cdot}120$
$C_{4}=+0{\cdot}213$	$C_{21}=-0{\cdot}266$	$C_{38}=-0{\cdot}623$	$C_{55}=-0{\cdot}304$
$C_{5}=-0{\cdot}124$	$C_{22}=+0{\cdot}538$	$C_{39}=-0{\cdot}730$	$C_{56}=+0{\cdot}133$
$C_{6}=-0{\cdot}384$	$C_{23}=+0{\cdot}349$	$C_{40}=+0{\cdot}473$	$C_{57}=-0{\cdot}096\ 6$
$C_{7}=+0{\cdot}710$	$C_{24}=+0{\cdot}819$	$C_{41}=-0{\cdot}276$	$C_{58}=+0{\cdot}033\ 2$
$C_{8}=-0{\cdot}475$	$C_{25}=+0{\cdot}505$	$C_{42}=+0{\cdot}257$	$C_{59}=-0{\cdot}146$
$C_{9}=+1{\cdot}173$	$C_{26}=+0{\cdot}048$	$C_{43}=-0{\cdot}940$	$C_{60}=+0{\cdot}018\ 4$
$C_{10}=+0{\cdot}139$	$C_{27}=-0{\cdot}340$	$C_{44}=-0{\cdot}067$	$C_{61}=+0{\cdot}118\ 5$
$C_{11}=+0{\cdot}877$	$C_{28}=+0{\cdot}180$	$C_{45}=+0{\cdot}340\ 5$	$C_{62}=+0{\cdot}022\ 6$
$C_{12}=\ \ 0{\cdot}056$	$C_{29}=-0{\cdot}129$	$C_{46}=+0{\cdot}106$	$C_{63}=-0{\cdot}123$
$C_{13}=+1{\cdot}139$	$C_{30}=+0{\cdot}502$	$C_{47}=+0{\cdot}022\ 2$	$C_{64}=+0{\cdot}639$
$C_{14}=-0{\cdot}231$	$C_{31}=-0{\cdot}825$	$C_{48}=+0{\cdot}049\ 2$	$C_{65}=-0{\cdot}121\ 6$
$C_{15}=+0{\cdot}031$	$C_{32}=-0{\cdot}327$	$C_{49}=+0{\cdot}043\ 2$	
$C_{16}=+0{\cdot}033$	$C_{33}=-0{\cdot}327$	$C_{50}=+0{\cdot}033\ 9$	
$C_{17}=-0{\cdot}465$	$C_{34}=-0{\cdot}024$	$C_{51}=+0{\cdot}018\ 2$	

Resulting corrections to angular directions.

″	″	″	″
(1)=−0·582	(35)=−0·189	(69)=+0·263	(103)=+0·139
(2)=+0·502	(36)=−0·078	(70)=−0·567	(104)=+0·171
(3)=+1·858	(37)=+0·092	(71)=+0·269	(105)=+0·094
(4)=−0·691	(38)=−0·195	(72)=−0·784	(106)=−0·404
(5)=−0·253	(39)=+0·370	(73)=+0·139	(107)=+0·535
(6)=−0·050	(40)=−1·091	(74)=+0·680	(108)=−0·567
(7)=+1·338	(41)=+0·201	(75)=−1·300	(109)=+0·079
(8)=−1·609	(42)=−0·363	(76)=+1·301	(110)=−0·309
(9)=−0·131	(43)=+0·057	(77)=−0·500	(111)=+0·262
(10)=−0·011	(44)=−0·108	(78)=+0·426	(112)=+0·261
(11)=+0·900	(45)=+0·136	(79)=+0·642	(113)=−0·403
(12)=−0·486	(46)=+1·169	(80)=−0·569	(114)=+0·311
(13)=−1·020	(47)=−1·036	(81)=−0·376	(115)=+0·225
(14)=+0·187	(48)=−0·151	(82)=+0·665	(116)=−0·940
(15)=+0·726	(49)=−0·094	(83)=−0·498	(117)=+0·548
(16)=+0·271	(50)=+0·316	(84)=+1·066	(118)=−0·308
(17)=−0·297	(51)=−1·025	(85)=−0·857	(119)=+0·165
(18)=+0·134	(52)=+1·992	(86)=−0·104	(120)=−0·229
(19)=−0·351	(53)=−0·285	(87)=+0·520	(121)=+0·372
(20)=+0·384	(54)=−0·024	(88)=−0·433	(122)=−0·940
(21)=−0·508	(55)=+0·508	(89)=+0·103	(123)=+0·276
(22)=+0·475	(56)=−0·296	(90)=−0·086	(124)=+0·289
(23)=−0·919	(57)=+0·097	(91)=+0·164	(125)=−0·103
(24)=+0·134	(58)=−0·274	(92)=+0·222	(126)=−0·395
(25)=−0·388	(59)=−0·948	(93)=−0·526	(127)=+0·873
(26)=+0·246	(60)=−0·566	(94)=+0·327	(128)=−0·132
(27)=+0·177	(61)=+0·266	(95)=−0·187	(129)=−2·239
(28)=−0·293	(62)=+1·163	(96)=−0·625	(130)=+0·442
(29)=+1·043	(63)=+0·359	(97)=+0·977	(131)=−2·446
(30)=−0·333	(64)=−1·206	(98)=−0·169	(132)=−0·370
(31)=−0·518	(65)=+0·578	(99)=+0·357	(133)=−0·094
(32)=−0·211	(66)=−0·826	(100)=+0·096	(134)=+0·115
(33)=−0·184	(67)=−0·234	(101)=−0·279	
(34)=+1·245	(68)=+1·689	(102)=−0·358	

(d) Adjusted triangles, Missouri.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
1	Morgan	52	31	52·47	−2·95	49·52	0·09	4·025 166 1	10 596·59
	Minoma	73	57	42·44	−0·58	41·86	0·10	4·108 280 8	12 831·60
	Insane Asylum	53	30	28·85	+0·05	28·90	0·09	4·030 746 3	10 733·62
				03·76			0·28		
2	Morgan	34	47	02·68	+1·48	04·16	0·12	4·065 715 2	11 633·63
	Insane Asylum	106	13	18·31	−0·05	18·26	0·12	4·291 822 7	19 580·45
	Kleinschmidt	38	59	39·80	−1·86	37·94	0·12	4·108 280 6	12 831·59
				00·79			0·36		
3	Patterson	27	55	43·13	−0·57	42·56	0·28	4·108 280 7	12 831·60
	Morgan	80	53	32·12	+1·60	33·72	0·27	4·432 183 7	27 051·02
	Insane Asylum	71	10	43·91	+0·64	44·55	0·28	4·413 828 3	25 931·54
				59·16			0·83		
4	Patterson	48	47	31·64	−0·14	31·50	0·31	4·291 822 7	19 580·45
	Morgan	46	06	29·44	+0·12	29·56	0·31	4·273 142 5	18 756·10
	Kleinschmidt	85	05	58·51	+1·36	59·87	0·31	4·413 828 2	25 931·53
				59·59			0·93		
5	Patterson	20	51	48·51	+0·43	48·94	0·15	4·065 715 2	11 633·63
	Insane Asylum	35	02	34·40	−0·69	33·71	0·15	4·273 142 7	18 756·11
	Kleinschmidt	124	05	38·31	−0·50	37·81	0·16	4·432 183 8	27 051·03
				01·22			0·46		
6	Kessler	26	33	09·78	+0·74	10·52	0·16	4·108 280 7	12 831·60
	Morgan	118	31	54·47	+2·51	56·98	0·15	4·401 715 1	25 218·26
	Insane Asylum	34	54	52·77	+0·20	52·97	0·16	4·215 616 4	16 429·20
				57·02			0·47		
7	Kessler	104	31	57·30	−0·16	57·14	0·22	4·413 828 2	25 931·53
	Morgan	37	38	22·35	+0·91	23·26	0·22	4·213 774 4	16 359·66
	Patterson	37	49	40·71	−0·45	40·26	0·22	4·215 616 3	16 429·20
				00·36			0·66		
8	Kessler	77	58	47·52	−0·89	46·63	0·34	4·432 183 7	27 051·02
	Insane Asylum	36	15	51·14	+0·44	51·58	0·34	4·213 774 4	16 359·66
	Patterson	65	45	23·84	−1·03	22·81	0·34	4·401 715 1	25 218·26
				02·50			1·02		
9	Tavern Rock	11	57	56·76	+1·05	57·81	0·09	4·215 616 4	16 429·20
	Morgan	11	41	41·90	−1·39	40·51	0·09	4·205 792 2	16 061·73
	Kessler	156	20	22·77	−0·82	21·95	0·09	4·502 439 2	31 800·88
				01·43			0·27		

(*d*) *Adjusted triangles, Missouri*—Continued.

No.	Stations.	Observed angles. °	′	″	Correction. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
10	Tavern Rock	52	51	02 ·39	+0 ·53	02 ·92	0 ·53	4 ·413 828 2	25 931 ·53
	Morgan	49	20	04 ·25	−0 ·47	03 ·78	0 ·53	4 ·392 304 2	24 677 ·67
	Patterson	77	48	54 ·81	+0 ·08	54 ·89	0 ·53	4 ·502 439 0	31 800 ·87
				01 ·45			1 ·59		
11	Tavern Rock	40	53	05 ·63	−0 ·52	05 ·11	0 ·22	4 ·213 774 4	16 359 ·66
	Kessler	99	07	39 ·93	+0 ·98	40 ·91	0 ·22	4 ·392 304 2	24 677 ·67
	Patterson	39	59	14 ·10	+0 ·54	14 ·64	0 ·22	4 ·205 792 1	16 061 ·72
				59 ·66			0 ·66		
12	Lynch	74	23	18 ·20	+1 ·43	19 ·63	0 ·34	4 ·392 304 2	24 677 ·67
	Tavern Rock	46	27	17 ·09	+0 ·63	17 ·72	0 ·33	4 ·268 865 6	18 572 ·29
	Patterson	59	09	22 ·44	+1 ·21	23 ·65	0 ·33	4 ·342 404 6	21 999 ·09
				57 ·73			1 ·00		
13	Halleck	67	41	32 ·99	+0 ·57	33 ·56	0 ·30	4 ·342 404 6	21 999 ·09
	Tavern Rock	48	56	08 ·18	−0 ·07	08 ·11	0 ·30	4 ·253 541 9	17 928 ·42
	Lynch	63	22	18 ·90	+0 ·33	19 ·23	0 ·30	4 ·327 493 3	21 256 ·58
				00 ·07			0 ·90		
14	Dieckhaus	53	57	56 ·33	+0 ·88	57 ·21	0 ·31	4 ·342 404 6	21 999 ·09
	Tavern Rock	87	50	06 ·22	+0 ·80	07 ·02	0 ·32	4 ·434 325 3	27 184 ·75
	Lynch	38	11	56 ·68	+0 ·03	56 ·71	0 ·31	4 ·225 901 2	16 822 ·91
				59 ·23			0 ·94		
15	Dieckhaus	88	47	52 ·54	+0 ·94	53 ·48	0 ·19	4 ·327 493 3	21 256 ·58
	Tavern Rock	38	53	58 ·04	+0 ·87	58 ·91	0 ·19	4 ·125 519 7	13 351 ·18
	Halleck	52	18	08 ·47	−0 ·29	08 ·18	0 ·19	4 ·225 901 1	16 822 ·91
				59 ·05			0 ·57		
16	Dieckhaus	34	49	56 ·21	+0 ·05	56 ·26	0 ·18	4 ·253 541 9	17 928 ·42
	Lynch	25	10	22 ·22	+0 ·31	22 ·53	0 ·18	4 ·125 519 6	13 351 ·18
	Halleck	119	59	41 ·46	+0 ·28	41 ·74	0 ·17	4 ·434 325 3	27 184 ·75
				59 ·89			0 ·53		
17	Peters	22	59	54 ·10	−0 ·17	53 ·93	0 ·18	4 ·225 901 2	16 822 ·91
	Dieckhaus	133	19	06 ·71	+1 ·35	08 ·06	0 ·18	4 ·495 915 3	31 326 ·75
	Tavern Rock	23	40	57 ·21	+1 ·34	58 ·55	0 ·18	4 ·237 928 1	17 295 ·30
				58 ·02			0 ·54		
18	Peters	50	17	08 ·53	+0 ·08	08 ·61	0 ·13	4 ·125 519 7	13 351 ·18
	Dieckhaus	44	31	14 ·17	+0 ·41	14 ·58	0 ·14	4 ·085 279 1	12 169 ·68
	Halleck	85	11	36 ·93	+0 ·29	37 ·22	0 ·14	4 ·237 928 1	17 295 ·30
				59 ·63			0 ·41		

(*d*) *Adjusted triangles*, *Missouri*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
19	Peters	65	19	39 ·12	+1 ·11	40 ·23	0 ·39	4 ·434 325 3	27 184 ·75
	Dieckhaus	79	21	10 ·38	+0 ·47	10 ·85	0 ·39	4 ·468 357 9	29 400 ·72
	Lynch	35	19	09 ·97	+0 ·12	10 ·09	0 ·39	4 ·237 927 9	17 295 ·29
				59 ·47			1 ·17		
20	Peters	27	17	14 ·43	+0 ·25	14 ·68	0 ·15	4 ·327 493 3	21 256 ·58
	Tavern Rock	15	13	00 ·83	−0 ·47	00 ·36	0 ·15	4 ·085 279 1	12 169 ·68
	Halleck	137	29	45 ·40	0 ·00	45 ·40	0 ·14	4 ·495 915 2	31 326 ·74
				00 ·66			0 ·44		
21	Peters	42	19	45 ·02	+1 ·28	46 ·30	0 ·52	4 ·342 404 6	21 999 ·09
	Tavern Rock	64	09	09 ·01	−0 ·54	08 ·47	0 ·52	4 ·468 357 8	29 400 ·71
	Lynch	73	31	06 ·65	+0 ·15	06 ·80	0 ·53	4 ·495 915 1	31 326 ·73
				00 ·68			1 ·57		
22	Peters	15	02	30 ·59	+1 ·03	31 ·62	0 ·08	4 ·253 541 9	17 928 ·42
	Halleck	154	48	41 ·61	−0 ·56	41 ·05	0 ·08	4 ·468 357 8	29 400 ·71
	Lynch	10	08	47 ·75	−0 ·18	47 ·57	0 ·08	4 ·085 279 0	12 169 ·68
				59 ·95			0 ·24		
23	Enochs Knob	36	50	47 ·02	+0 ·26	47 ·28	0 ·19	4 ·125 519 7	13 351 ·18
	Dieckhaus	94	25	52 ·64	−0 ·93	51 ·71	0 ·19	4 ·346 305 9	22 197 ·59
	Halleck	48	43	21 ·41	+0 ·17	21 ·58	0 ·19	4 ·223 549 1	16 732 ·05
				01 ·07			0 ·57		
24	Enochs Knob	67	04	54 ·73	+0 ·79	55 ·52	0 ·19	4 ·237 928 0	17 295 ·29
	Dieckhaus	49	54	38 ·47	−1 ·35	37 ·12	0 ·18	4 ·157 320 8	14 365 ·50
	Peters	63	00	27 ·50	+0 ·42	27 ·92	0 ·19	4 ·223 549 1	16 732 ·05
				00 ·70			0 ·56		
25	Enochs Knob	30	14	07 ·71	+0 ·53	08 ·24	0 ·14	4 ·085 279 1	12 169 ·68
	Halleck	36	28	15 ·52	+0 ·12	15 ·64	0 ·14	4 ·157 320 9	14 365 ·50
	Peters	113	17	36 ·03	+0 ·50	36 ·53	0 ·13	4 ·346 306 0	22 197 ·60
				59 ·26			0 ·41		
26	Jacobs	44	39	46 ·94	+1 ·92	48 ·86	0 ·21	4 ·157 320 8	14 365 ·50
	Enochs Knob	63	12	38 ·45	−0 ·80	37 ·65	0 ·21	4 ·261 091 2	18 242 ·79
	Peters	72	07	33 ·39	+0 ·73	34 ·12	0 ·21	4 ·288 917 1	19 449 ·89
				58 ·78			0 ·63		
27	Berger	7	16	09 ·33	−0 ·68	08 ·65	0 ·04	4 ·223 549 1	16 732 ·05
	Dieckhaus	5	56	37 ·68	+3 ·02	40 ·70	0 ·04	4 ·136 581 7	13 695 ·62
	Enochs Knob	166	47	11 ·16	−0 ·38	10 ·78	0 ·05	4 ·480 404 0	30 227 ·62
				58 ·17			0 ·13		

(*d*) *Adjusted triangles, Missouri*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
28	Berger	34	53	53 ·96	−0 ·29	53 ·67	0 ·37	4 ·237 928 0	17 295 ·29
	Dieckhaus	55	51	16 ·15	+1 ·68	17 ·83	0 ·37	4 ·398 271 5	25 019 ·03
	Peters	89	14	49 ·75	−0 ·15	49 ·60	0 ·36	4 ·480 403 9	30 227 ·62
				59 ·86			1 ·10		
29	Berger	27	37	44 ·63	+0 ·38	45 ·01	0 ·13	4 ·157 320 8	14 365 ·50
	Enochs Knob	126	07	54 ·11	−0 ·41	53 ·70	0 ·14	4 ·398 271 6	25 019 ·10
	Peters	26	14	22 ·25	−0 ·56	21 ·69	0 ·13	4 ·136 581 8	13 695 ·62
				00 ·99			0 ·40		
30	Berger	74	22	47 ·40	+1 ·22	48 ·62	0 ·20	4 ·288 917 1	19 449 ·89
	Enochs Knob	62	55	15 ·66	+0 ·39	16 ·05	0 ·20	4 ·254 835 1	17 981 ·88
	Jacobs	42	41	55 ·34	+0 ·59	55 ·93	0 ·20	4 ·136 581 8	13 695 ·62
				58 ·40			0 ·60		
31	Berger	46	45	02 ·77	+0 ·83	03 ·60	0 ·28	4 ·261 091 2	18 242 ·79
	Peters	45	53	11 ·14	+1 ·29	12 ·43	0 ·28	4 ·254 835 2	17 981 ·88
	Jacobs	87	21	42 ·28	+2 ·52	44 ·80	0 ·27	4 ·398 271 6	25 019 ·10
				56 ·19			0 ·83		
32	Winter	60	57	15 ·09	+0 ·54	15 ·63	0 ·21	4 ·254 835 1	17 981 ·88
	Berger	45	13	55 ·72	+0 ·90	56 ·62	0 ·21	4 ·164 447 1	14 603 ·17
	Jacobs	73	48	48 ·01	+0 ·38	48 ·39	0 ·22	4 ·295 641 6	19 753 ·39
				58 ·82			0 ·64		
33	Gasconade	47	32	33 ·85	+2 ·60	36 ·45	0 ·23	4 ·254 835 1	17 981 ·88
	Berger	93	14	33 ·91	+0 ·09	34 ·00	0 ·24	4 ·386 207 1	24 333 ·64
	Jacobs	39	12	51 ·65	−1 ·40	50 ·25	0 ·23	4 ·187 769 5	15 408 ·82
				59 ·41			0 ·70		
34	Gasconade	81	30	04 ·55	+0 ·80	05 ·35	0 ·19	4 ·295 641 6	19 753 ·39
	Berger	48	00	38 ·19	−0 ·80	37 ·39	0 ·19	4 ·171 580 7	14 845 ·02
	Winter	50	29	16 ·91	+0 ·92	17 ·83	0 ·19	4 ·187 769 2	15 408 ·81
				59 ·65			0 ·57		
35	Gasconade	33	57	30 ·70	−1 ·80	28 ·90	0 ·17	4 ·164 447 1	14 603 ·17
	Jacobs	34	35	56 ·36	+1 ·78	58 ·14	0 ·17	4 ·171 580 7	14 845 ·02
	Winter	111	26	32 ·00	+1 ·47	33 ·47	0 ·17	4 ·386 207 2	24 333 ·65
				59 ·06			0 ·51		
36	Turnpike Bluff	49	40	55 ·91	+1 ·04	56 ·95	0 ·12	4 ·171 580 7	14 845 ·02
	Gasconade	100	39	12 ·31	−0 ·07	12 ·24	0 ·12	4 ·281 806 9	19 134 ·05
	Winter	29	39	52 ·22	−1 ·05	51 ·17	0 ·12	3 ·983 888 9	9 635 ·82
				00 ·44			0 ·36		

(*d*) *Adjusted triangles*, *Missouri*—Continued.

No.	Stations.	Observed angles. °	′	″	Correction. ″	Spherical angles. ″	Spherical excess. ″	*Log s.*	Distances in metres.
37	Geyer	29	23	26·55	+0·54	27·09	0·13	3·983 888 9	9 635·82
	Turnpike Bluff	96	40	21·27	−0·12	21·15	0·13	4·290 064 3	19 501·33
	Gasconade	53	56	13·14	−0·99	12·15	0·13	4·200 624 5	15 871·74
				00·96			0·39		
38	Geyer	78	36	17·82	+0·35	18·17	0·18	4·281 806 9	19 134·05
	Turnpike Bluff	46	59	25·36	−1·16	24·20	0·19	4·154 509 8	14 272·82
	Winter	54	24	18·19	0·00	18·19	0·19	4·200 624 5	15 871·74
				01·37			0·56		
39	Geyer	49	12	51·27	−0·19	51·08	0·18	4·171 580 7	14 845·02
	Gasconade	46	42	59·17	+0·93	60·10	0·18	4·154 509 8	14 272·82
	Winter	84	04	10·41	−1·05	09·36	0·18	4·290 064 4	19 501·34
				00·85			0·54		
40	Bradford	2	56	49·38	+1·603	50·983	0·021	3·983 888 9	9 635·82
	Turnpike Bluff	171	38	43·51	−0·480	43·030	0·021	4·435 020 1	27 228·27
	Gasconade	5	24	27·26	−1·210	26·050	0·021	4·246 958 2	17 658·68
				00·15			0·063		
41	Bradford	30	17	34·39	+0·46	34·85	0·24	4·281 806 9	19 134·05
	Turnpike Bluff	121	57	47·60	−1·52	46·08	0·25	4·507 610 4	32 181·81
	Winter	27	44	38·97	+0·83	39·80	0·24	4·246 958 2	17 658·68
				00·96			0·73		
42	Bradford	48	32	18·62	+0·98	19·60	0·23	4·200 624 5	15 871·74
	Turnpike Bluff	74	58	22·24	−0·36	21·88	0·23	4·310 797 1	20 454·89
	Geyer	56	29	20·16	−0·95	19·21	0·23	4·246 958 3	17 658·68
				01·02			0·69		
43	Bradford	27	20	45·01	−1·15	43·86	0·34	4·171 580 7	14 845·02
	Gasconade	95	14	45·05	+1·14	46·19	0·34	4·507 610 3	32 181·80
	Winter	57	24	31·19	−0·22	30·97	0·34	4·435 019 9	27 228·26
				01·25			1·02		
44	Bradford	45	35	29·24	−0·62	28·62	0·34	4·290 064 4	19 501·34
	Gasconade	48	31	45·88	+0·22	46·10	0·34	4·310 797 2	20 454·89
	Geyer	85	52	46·71	−0·42	46·29	0·33	4·435 020 1	27 228·27
				01·83			1·01		
45	Bradford	18	14	44·23	+0·53	44·76	0·17	4·154 509 8	14 272·82
	Winter	26	39	39·22	−0·83	38·39	0·17	4·310 797 4	20 454·90
	Geyer	135	05	37·98	−0·61	37·37	0·18	4·507 610 6	32 181·82
				01·43			0·52		

(*d*) *Adjusted triangles, Missouri*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
46	Pilot Knob	30	08	45·12	+0·85	45·97	0·37	4·246 958 3	17 658·68
	Bradford	103	17	45·81	+0·72	46·53	0·37	4·534 276 6	34 219·73
	Turnpike Bluff	46	33	30·53	−1·92	28·61	0·37	4·407 055 0	25 530·25
				01·46			1·11		
47	Pilot Knob	50	35	25·93	+0·34	26·27	0·36	4·310 797 2	20 454·89
	Bradford	54	45	27·19	−0·26	26·93	0·36	4·334 897 4	21 622·07
	Geyer	74	39	07·26	+0·62	07·88	0·36	4·407 055 0	25 530·25
				00·38			1·08		
48	Pilot Knob	20	26	40·81	−0·51	40·30	0·22	4·200 624 5	15 871·74
	Turnpike Bluff	28	24	51·71	+1·56	53·27	0·22	4·334 897 2	21 622·07
	Geyer	131	08	27·42	−0·33	27·09	0·22	4·534 276 6	34 219·73
				59·94			0·66		
49	McDaniel	111	27	01·00	−0·50	00·50	0·18	4·407 055 0	25 530·25
	Bradford	35	02	45·56	−0·37	45·19	0·19	4·197 315 3	15 751·26
	Pilot Knob	33	30	15·62	−0·75	14·87	0·19	4·180 164 5	15 141·35
				02·18			0·56		
50	Kennedy	37	10	29·58	+0·57	30·15	0·29	4·197 315 3	15 751·26
	McDaniel	85	42	50·95	+0·54	51·49	0·29	4·414 881 9	25 994·53
	Pilot Knob	57	06	39·17	+0·06	39·23	0·29	4·340 233 8	21 889·40
				59·70			0·87		
51	Cedar	28	02	53·69	−0·66	53·03	0·35	4·180 164 5	15 141·35
	Bradford	58	02	56·54	−0·08	56·46	0·35	4·436 524 1	27 322·73
	McDaniel	93	54	11·64	−0·08	11·56	0·35	4·506 863 6	32 126·51
				01·87			1·05		
52	Cedar	46	23	46·65	+0·72	47·37	0·47	4·340 233 8	21 889·40
	McDaniel	68	55	56·41	+0·03	56·44	0·48	4·450 372 5	28 208·01
	Kennedy	64	40	18·00	−0·39	17·61	0·47	4·436 524 0	27 322·72
				01·06			1·42		
53	Belshe	53	41	30·23	+0·21	30·44	0·63	4·450 372 5	28 208·01
	Cedar	50	58	19·36	−0·09	19·27	0·63	4·434 452 5	27 192·71
	Kennedy	75	20	12·63	−0·45	12·18	0·63	4·529 742 1	33 864·30
				02·22			1·89		
54	Moreau	53	02	17·25	−0·39	16·86	0·61	4·450 372 5	28 208·01
	Cedar	80	07	37·82	−1·25	36·57	0·60	4·541 327 5	34 779·83
	Kennedy	46	50	07·75	+0·64	08·39	0·61	4·410 769 2	25 749·52
				02·82			1·82		

(d) *Adjusted triangles. Missouri*—Completed.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
55	Moreau	103	03	06·64	−0·68	05·96	0·36	4·529 742 1	33 864·30
	Cedar	29	09	18·46	−1·17	17·29	0·36	4·228 788 5	16 935·13
	Belshe	47	47	35·48	−2·35	37·83	0·36	4·410 769 2	25 749·52
				00·58			1·08		
56	Moreau	50	00	49·39	−0·29	49·10	0·38	4·434 452 5	27 192·71
	Kennedy	28	30	04·88	−1·10	03·78	0·38	4·228 788 6	16 935·13
	Belshe	101	29	05·71	−2·56	08·27	0·39	4·541 327 5	34 779·83
				59·98			1·15		
57	Moreau	79	54	09·54	+1·27	10·81	0·21	4·305 854 3	20 223·41
	Belshe	44	33	60·55	−2·45	58·10	0·20	4·158 804 1	14 414·65
	High Point	55	31	52·14	−0·44	51·70	6·20	4·228 788 2	16 935·12
				02·23			0·61		
58	Moreau	141	49	21·81	−0·54	21·27	0·13	4·486 091 7	30 626·10
	Belshe	18	11	32·76	−2·45	30·31	0·14	4·189 463 0	15 469·03
	Christian	19	59	06·59	+2·24	08·83	0·14	4·228 788 2	16 935·12
				01·16			0·41		
59	Moreau	61	55	12·27	−1·81	10·46	0·17	4·187 515 2	15 399·80
	High Point	62	24	21·82	+0·44	22·26	0·16	4·189 463 0	15 469·03
	Christian	55	40	25·54	+2·24	27·78	0·17	4·158 804 2	14 414·65
				59·63			0·50		
60	Medlock	88	14	46·23	+0·47	46·70	0·44	4·529 742 1	33 864·30
	Cedar	61	08	27·52	+0·32	27·84	0·43	4·472 355 4	29 672·59
	Belshe	30	36	46·48	+0·28	46·76	0·43	4·236 863 6	17 252·96
				00·23			1·30		
61	Medlock	108	35	16·95	+0·08	17·03	0·20	4·410 769 2	25 749·52
	Cedar	31	59	09·06	+1·49	10·55	0·20	4·158 078 8	14 390·60
	Moreau	39	25	33·01	+0·01	33·02	0·20	4·236 863 6	17 252·96
				59·02			0·60		
62	Medlock	20	20	30·72	−0·40	30·32	0·13	4·228 788 2	16 935·12
	Belshe	17	10	49·00	+2·08	51·08	0·13	4·158 078 5	14 390·59
	Moreau	142	28	39·65	−0·67	38·98	0·12	4·472 355 0	29 672·56
				59·37			0·38		
63	Medlock	75	09	10·42	+0·21	10·63	0·44	4·486 091 7	30 626·10
	Belshe	35	22	21·76	−0·37	21·39	0·45	4·263 435 0	18 341·51
	Christian	69	28	29·19	+0·13	29·32	0·45	4·472 355 1	29 672·56
				01·37			1·34		
64	Medlock	54	48	39·70	+0·60	40·30	0·18	4·189 463 0	15 469·03
	Moreau	75	41	58·54	+1·22	59·76	0·19	4·263 434 9	18 341·50
	Christian	49	29	22·60	−2·11	20·49	0·18	4·158 078 5	14 390·59
				00·84			0·55		

(*e*) *The precision of the adjusted triangulation.*

To get a close estimate of the precision of this triangulation, we determine first the mean error of an angle resulting from the adjustment. We have $m = \sqrt{\frac{2\,[pvv]}{c}}$, where $p = 1$ and $[vv] = 62{\cdot}45$ and $c = 65$; hence $m = \pm\,1''{\cdot}39$.

The probable error in length of any line of the series due to the angular measures is found by the usual formulæ—

$$u_{a_n} = \tfrac{2}{3}\,(\delta_{a_n})^{-2} \sum_{a_1}^{a} \left[\delta_A^2 + \delta_A\,\delta_B + \delta_B^2\right] \text{ and } e_{a_n} = 0{\cdot}674\,5\,m\sqrt{u_{a_n}}$$

Suppose the series divided into three parts by the lines Tavern Rock to Lynch and Bradford to Pilot Knob, and compute the probable error in length of each of these lines. For the former we have $\delta_{a_n} = 19{\cdot}8$. Starting from the side Insane Asylum to Kleinschmidt of the American Bottom Base Net, we have $\Sigma = 22{\cdot}8$ (4 triangles), $e_{a_n} = \pm\,0{\cdot}185$ metre, $e_b = \pm\,0{\cdot}286$ metre, and $e_1 = \pm\,0{\cdot}341$ metre. Starting from the side Christian to Belshe of the Versailles Base Net, we have $\Sigma = 95{\cdot}2$ (15 triangles), $e_{a_n} = \pm\,0{\cdot}377$ metre, $e_b = \pm\,0{\cdot}086$ metre, and $e_2 = \pm\,0{\cdot}387$ metre.

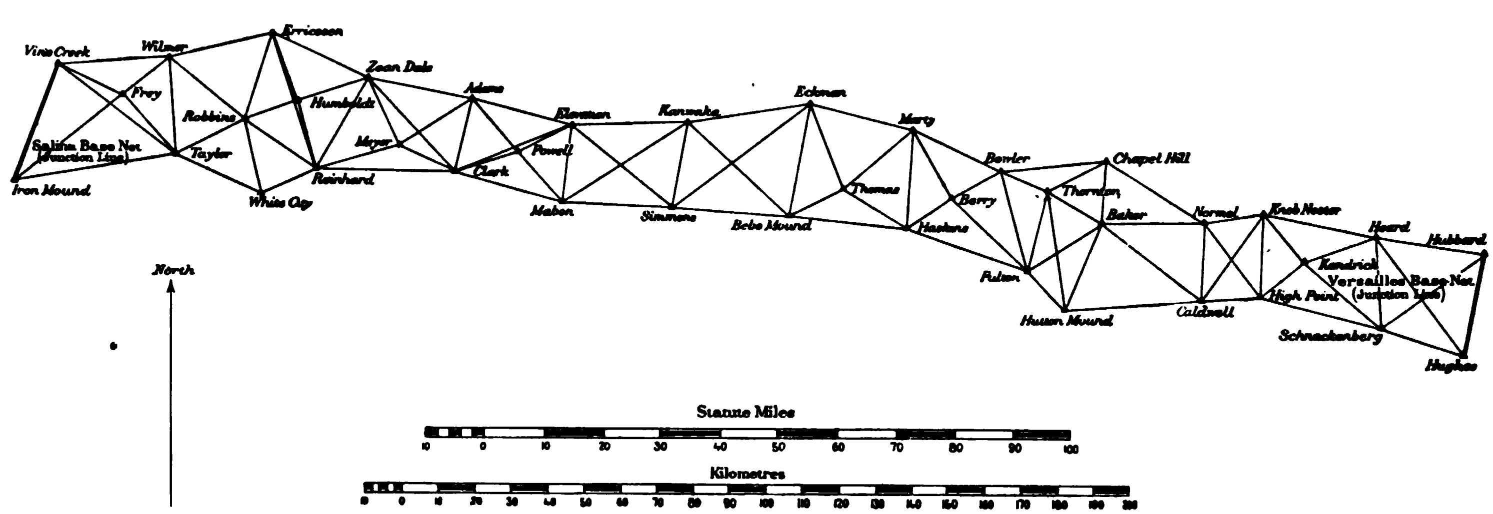
Probable error of Tavern Rock to Lynch as a side of the adjusted triangulation, $e = \frac{e_1 e_2}{\sqrt{e_1^2 + e_2^2}} = \pm\,0{\cdot}256$ metre, or about $\frac{1}{86\,000}$ part of the length. Similarly, for the side Bradford to Pilot Knob $\delta_{a_n} = 17$ in units of the sixth place of decimals in the logarithm. Starting from the side Insane Asylum to Kleinschmidt $\Sigma = 84{\cdot}3$ (13 triangles), $e_{a_n} = \pm\,0{\cdot}413$ metre, $e_b = \pm\,0{\cdot}332$ metre, and $e_1 = \pm\,0{\cdot}530$ metre.

Starting from the side Christian to Belshe $\Sigma = 33{\cdot}7$ (6 triangles), $e_{a_n} = \pm\,0{\cdot}261$ metre, $e_b = \pm\,0{\cdot}100$ metre, and $e_2 = \pm\,0{\cdot}280$ metre. Probable error in length of Bradford to Pilot Knob as a side of the adjusted triangulation $e = \frac{e_1 e_2}{\sqrt{e_1^2 + e_2^2}} = \pm\,0{\cdot}248$ metre, or about $\frac{1}{103\,000}$ part of the length.

The effect on the arc is approximately (the distances being measured along the thirty-ninth parallel between the projections of the middle points of the terminal lines)—

Terminal lines.	Distance.	Probable errors.		Average.	
	km.				*m.*
Insane Asylum and Kleinschmidt to Tavern Rock and Lynch	38	$\frac{1}{77\,000}$	$\frac{1}{86\,000}$	$\frac{1}{81\,000}$	$\pm 0{\cdot}47$
Tavern Rock and Lynch to Bradford and Pilot Knob	90	$\frac{1}{86\,000}$	$\frac{1}{103\,000}$	$\frac{1}{94\,000}$	$0{\cdot}96$
Bradford and Pilot Knob to Christian and Belshe	60	$\frac{1}{103\,000}$	$\frac{1}{255\,000}$	$\frac{1}{147\,000}$	$0{\cdot}42$
	188			Sum	$\pm 1{\cdot}85$

VERSAILLES BASE NET TO SALINA BASE NET
MISSOURI-KANSAS SERIES
MO. AND KAN.



7. THE MISSOURI-KANSAS SERIES OF TRIANGLES, 1880–1890.

(*a*) *Introduction.*

Between the Versailles Base, which is located about the middle line of the State of Missouri, and the Salina Base, which occupies a similar relative position in the State of Kansas, the triangulation gradually ascends the Western plains with a narrow and uniform width imposed upon it by the absence of any marked elevations above the general level. The work was in charge of Assistant F. D. Granger, and its extent between the sides of the base nets and measured along the axis of the triangulation is nearly 400 kilometres, or about 248 statute miles.

The general character of the ground traversed by the belt of triangulation is open and rolling, well settled in the eastern half with a large percentage of land under cultivation; in the western part the settlements are more sparse with land either under cultivation or fenced in for cattle ranges.

The ground rises gradually from about 1 050 feet above the sea level near Versailles to about 1 250 feet near Salina. The theodolite was elevated at nearly every station throughout the entire series—its average height above the ground being 25 feet, but at a number of stations its elevation approximated 57 feet, and at one place only was it greater than this (105 feet at Hughes). The signals employed upon the work were poles 20 feet long and 4 inches in diameter, heliotropes being rarely required except on the longer (diagonal) lines during smoky weather. A direction theodolite (35 centimetres in diameter) was used for the observations, and measures were made in 17 positions of the azimuth circle, with two series (*D.* and *R.*) in each position. As a rule the observations were pursued during the afternoon hours every favorable day. Zenith distances and vertical angle measures for differences of heights were carried through the entire work.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90.*

Hubbard, Morgan County, Missouri. October 29 to November 12, 1880. 35-centimetre theodolite, No. 10. Telescope above ground 13·99 metres. F. D. Granger and T. P. Borden, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Cole	0	00	00·00	±0·10	+0·27		00·27
	High Point	19	27	23·21	0·16	−0·95		22·26
	Versailles North Base	55	58	59·68	0·14	+0·57		60·25
	Hughes	82	13	13·27	0·16	+0·31		13·58
3	Schnackenberg	125	22	11·35	0·18		−0·35	11·00
	Sedalia Spire	166	10	13·78	0·22			
4	Heard	168	31	22·35	0·17		+0·28	22·63
	Christian	350	25	26·60	0·14	−0·20		26·40

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·90.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Continued.

Hughes, Morgan County, Missouri. September 8 to September 26, 1880. 35-centimetre theodolite, No. 10. Telescope above ground 32·19 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Versailles North Base	0	00	00·00	±0·10	−0·04		59·96
	Hunter (Versailles South Base)	33	10	50·59	0·12	−0·20		50·39
1	Schnackenberg	229	36	09·83	0·17		+0·50	10·33
	Sedalia, German Methodist Church spire	261	32	53·97	0·44			
2	Heard	264	26	26·61	0·14		−0·79	25·82
	Hubbard	314	13	16·91	0·13	−0·32		16·59
	Cole	339	57	16·87	0·14	−0·20		16·67
	Christian	358	46	13·33	0·21	+0·75		14·08

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·90.

Schnackenberg, Benton County, Missouri. September 7 to September 22, 1882. 35-centimetre theodolite, No. 10. Telescope above ground 16·86 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
7	Heard	0	00	00·00	±0·11	+0·21	00·21
8	Hubbard	58	46	54·03	0·14	−0·28	53·75
9	Hughes	111	00	51·59	0·14	+0·14	51·73
5	High Point Tebo	288	09	14·80	0·13	+0·38	15·18
6	Kendrick	314	03	28·81	0·16	−0·45	28·36

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·83.

Heard, Pettis County, Missouri. October 1 to October 6, 1880. 35-centimetre theodolite, No. 10. Telescope above ground 16·43 metres. F. D. Granger, observer. August 22 to September 1, 1882. 35-centimetre theodolite, No. 10. Telescope above ground 16·43 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
12	Schnackenberg	0	00	00·00	±0·08	+0·29	00·29
	Sedalia	61	55	43·47	0·35		
13	Kendrick	76	13	14·27	0·13	−0·02	14·25
14	Knob Noster	106	10	35·58	0·15	+0·06	35·64
10	Hubbard	281	56	03·80	0·16	−0·16	03·64
11	Hughes	325	51	06·09	0·13	−0·16	05·93

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·81.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Continued.

Kendrick, Pettis County, Missouri. September 26 to October 3, 1882. 35-centimetre theodolite, No. 10. Telescope above ground 7·44 metres. F. D. Granger and J. E. McGrath, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
17	High Point Tebo	0	00	00·00	±0·12	+0·14	00·14
	Shoemakers house, cupola, lightning rod	86	19	08·04	0·36		
18	Knob Noster	88	57	59·87	0·14	−0·14	59·73
	Lamont, Christian Church spire	131	28	30·81	0·40		
15	Heard	200	27	41·67	0·18	0·16	41·51
16	Schnackenberg	258	17	56·77	0·24	−0·16	56·93
	Green Ridge Church chimney	283	59	21·96	0·83		
	Tomlin's house, SE. chimney	351	09	51·26	0·46		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·10

High Point Tebo, Johnson County, Missouri. October 9 to October 20, 1882. 35-centimetre theodolite, No. 10. Telescope above ground 16·61 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
26	Knob Noster	0	00	00·00	±0·10	−0·29	59·71
27	Kendrick	47	37	45·97	0·18	−0·30	45·67
	Tomlins house, SE. chimney	51	09	26·36	0·30		
	Green Ridge, Congregational Church chimney	67	24	43·11	0·36		
28	Schnackenberg	100	01	30·08	0·16	+0·25	30·33
	Windsor Schoolhouse cupola	137	26	26·20	0·26		
24	Caldwell	262	20	03·48	0·12	+0·07	03·55
	High Point Tebo Church chimney	314	11	32·97	0·55		
25	Normal	320	09	08·10	0·11	+0·26	08·36

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·87.

Knob Noster, Johnson County, Missouri. October 25 to November 14, 1882. 35-centimetre theodolite, No. 10. Telescope above ground 7·68 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
21	High Point Tebo	0	00	00·00	±0·10	+0·24	00·24
22	Caldwell	33	03	28·71	0·15	+0·40	29·11
23	Normal	78	42	43·55	0·15	−0·46	43·09
	Warrensburg Old School Presbyterian Church spire	80	50	38·68	0·34		
	Hazel Hill	122	39	53·78	0·22		
	Cooks Knob, pole on ice house	188	28	53·68	0·29		
	La Monte, Campbellite Church belfry	264	47	35·12	0·31		
19	Heard	278	02	47·62	0·14	−0·10	47·52
20	Kendrick	316	35	45·22	0·16	−0·08	45·14
	Shoemaker's house, Cupola lightning rod	322	43	25·09	0·46		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·93.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Continued.

Normal, Johnson County, Missouri. June 20 to July 2, 1883. 35 centimetre theodolite, No. 10. Telescope above ground 28·19 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
34	Knob Noster	0	00	00·00	±0·11	+0·11	00·11
35	High Point Tebo	61	26	26·69	0·12	+0·13	26·82
36	Caldwell	101	09	51·58	0·15	−0·47	51·11
	Holden, Methodist Church spire	174	28	42·15	0·39		
37	Baker	187	12	20·35	0·15	+0·08	20·43
38	Chapel Hill	218	32	51·69	0·15	+0·14	51·83
	Hazel Hill	272	14	28·35	0·31		
	Warrensburg Presbyterian Church spire	276	06	32·04	0·67		
	Cooks Knob	334	04	54·0	0·38		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·91.

Caldwell, Johnson County, Missouri. July 11 to July 19, 1883. 35-centimetre theodolite, No. 10. Telescope above ground 12·80 metres. F. D. Granger and J. E. McGrath, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
33	High Point Tebo	0	00	00·00	±0·11	−0·07	$\overline{59}$·93
	Windsor Public School flagstaff	15	22	18·50	0·27		
29	Hutton Mound	179	50	51·00	0·10	+0·09	51·09
30	Baker	221	18	16·76	0·12	−0·29	16·47
	Holden Methodist Church tall white spire	222	08	36·05	0·38		
	Warrensburg Presbyterian Church spire	277	24	02·57	0·18		
31	Normal	277	32	28·07	0·12	+0·10	28·17
32	Knob Noster	310	43	23·89	0·11	+0·17	24·06

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·68.

Hutton Mound, Cass County, Missouri. July 28 to August 15, 1883. 35-centimetre theodolite, No. 10. Telescope above ground 5·52 metres. F. D. Granger and J. E. McGrath, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
49	Fulton	0	00	00·00	±0·08	−0·36	$\overline{59}$·64
50	Thornton	35	45	53·25	0·14	+0·24	53·49
	Staley Mound, Staley's house chimney.	39	48	37·33	0·30		
51	Baker	68	01	20·70	0·10	−0·09	20·61
	Kingsville Public School cupola	69	07	24·90	0·29		
	Holden Methodist Church tall white spire	87	33	58·36	0·46		
52	Caldwell	132	16	05·80	0·16	+0·21	06·01
	Austin Church spire	289	56	52·41	0·38		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·80.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Continued.

Baker, Johnson County, Missouri. September 15 to September 28, 1883. 35-centimetre theodolite, No. 10. Telescope above ground 7·38 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
43	Thornton	0	00	00·00	±0·09	−0·06	59·94
44	Chapel Hill	65	09	26·15	0·15	−0·23	25·92
39	Normal	151	40	60·55	0·14	−0·32	60·23
40	Caldwell	189	24	20·34	0·19	+0·42	20·76
41	Hutton Mound	263	42	12·22	0·12	−0·06	12·16
42	Fulton	300	07	28·51	0·16	+0·25	28·76

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·86.

Chapel Hill, Johnson County, Missouri. October 6 to October 16, 1883. 35-centimetre theodolite, No. 10. Telescope above ground 16·55 metres. F. D. Granger and J. E. McGrath, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
46	Baker	0	00	00·00	±0·09	+0·18	00·18
47	Thornton	58	26	56·61	0·12	+0·07	56·68
48	Bowler	80	58	45·80	0·12	0·00	45·80
45	Normal	297	52	04·88	0·11	−0·25	04·63

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·65.

Bowler, Jackson County, Missouri. July 29 to August 13, 1884. 35-centimetre theodolite, No. 10. Telescope above ground 8·26 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
65	Thornton	0	00	00·00	±0·09	+0·11	00·11
66	Fulton	50	05	23·86	0·12	−0·18	23·68
67	Berry	127	57	45·99	0·13	−0·24	45·75
68	Marty	180	46	17·22	0·16	+0·74	17·96
64	Chapel Hill	329	49	33·21	0·14	−0·43	32·78

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·76.

Thornton, Cass County, Missouri. October 23 to November 1, 1883. 35-centimetre theodolite, No. 10. Telescope above ground 7·41 metres. F. D. Granger and J. E. McGrath, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″
60	Baker	0	00	00·00	±0·09	+0·03	00·03
	Staley Mound, Staley's house chimney.	46	43	34·99	0·27		
61	Hutton Mound	51	26	46·51	0·13	−0·26	46·25
62	Fulton	76	18	04·48	0·10	+0·05	04·53
	Raymore, Christian Church spire.	140	50	43·25	0·31		
63	Bowler	176	18	37·76	0·12	0·00	37·76
	Lees Summit, South Methodist Church cupola.	189	08	01·67	0·21		
	Hicks City, Christian Union Church spire.	301	39	52·88	0·18		
59	Chapel Hill.	303	36	21·65	0·10	−0·18	21·83

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·66.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Continued.

Fulton, Cass County, Missouri. August 20 to September 8, 1883. 35-centimetre theodolite, No. 10. Telescope above ground 6·68 metres. F. D. Granger and J. E. McGrath, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
58	Hutton Mound	0	00	00 ·00	±0 ·07	−0 ·49	00 ·49
	Austin, Methodist Church spire	42	26	49 ·96	0 ·36		
	Harrisonville, tall white church spire	151	17	56 ·76	0 ·20		
53	Haskin	153	54	48 ·55	0 ·11	+0 ·47	49 ·02
54	Berry	177	54	45 ·34	0 ·10	−1 ·12	44 ·22
	Belton, South Methodist Church spire	179	28	14 ·75	0 ·21		
55	Bowler	210	43	07 ·65	0 ·16	+0 ·26	07 ·91
56	Thornton	240	37	11 ·68	0 ·15	+0 ·20	11 ·88
	Staley Mound, Staley's house chimney	281	03	40 ·30	0 ·30		
57	Baker	284	26	37 ·43	0 ·14	−0 ·30	37 ·13
	Kingsville, Public School cupola	288	01	13 ·18	0 ·34		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·76.

Berry, Cass County, Missouri. August 23 to August 30, 1884. 35-centimetre theodolite, No. 10. Telescope above ground 7·25 metres. F. D. Granger, observer.

		°	′	″	″	″	″
69	Bowler	0	00	00 ·00	±0 ·12	+0 ·05	00 ·05
70	Fulton	69	19	14 ·95	0 ·12	+0 ·47	15 ·42
71	Haskin	168	17	52 ·31	0 ·11	+0 ·03	52 ·34
72	Marty	270	21	15 ·87	0 ·11	−0 ·55	15 ·32

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·68.

Marty, Johnson County, Kansas. August 1 to August 13, 1885. 35-centimetre theodolite, No. 10. Telescope above ground 19·60 metres. F. D. Granger and E. D. Preston, observers.

		°	′	″	″	″	″
74	Berry	0	00	00 ·00	±0 ·11	+0 ·02	00 ·02
75	Haskin	29	51	52 ·14	0 ·12	+0 ·83	52 ·97
76	Thomas	76	46	28 ·08	0 ·18	−0 ·18	27 ·90
77	Eckman	128	55	42 ·16	0 ·16	−0 ·04	42 ·12
73	Bowler	322	27	16 ·73	0 ·13	−0 ·63	16 ·10

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·82.

Haskin, Johnson County, Kansas. August 25 to September 6, 1885. 35-centimetre theodolite, No. 10. Telescope above ground 19·69 metres. F. D. Granger, observer.

		°	′	″	″	″	″
81	Berry	0	00	00 ·00	±0 ·08	−0 ·32	59 ·68
82	Fulton	57	01	28 ·22	0 ·14	+0 ·37	28 ·59
78	Bébé Mound	225	36	03 ·25	0 ·12	+0 ·25	03 ·50
79	Thomas	250	54	47 ·31	0 ·17	−0 ·12	47 ·19
80	Marty	311	55	15 ·05	0 ·13	−0 ·18	14 ·87

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·78.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Continued.

Thomas, Johnson County, Kansas. October 6 to October 20, 1885. 35-centimetre theodolite, No. 10. Telescope above ground 16·64 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
85	Bébé Mound	0	00	00·00	±0·11	+0·20	00·20
	Blue Mound	43	45	52·07	0·15		
86	Eckman	95	12	49·21	0·16	−0·17	49·04
83	Marty	167	04	26·03	0·15	+0·03	26·06
84	Haskin	239	09	24·82	0·15	−0·06	24·76

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·85.

Eckman, Leavenworth County, Kansas. October 30 to November 30, 1885. 35-centimetre theodolite, No. 10. Telescope above ground 15·39 metres. E. D. Preston, observer. July 11 to July 18, 1887. 35-centimetre theodolite, No. 10. Telescope above ground 15·29 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
89	Bébé Mound	0	00	00·00	*±0·14 † ·08	−0·29	59·71
	Blue Mound	35	55	52·43	0·19		
90	Simmons	43	07	59·12	0·09	+0·40	59·52
	Carson	48	59	59·53	0·07		
91	Kanwaka	71	18	07·35	0·09	−0·04	07·31
	Second Presbyterian Church spire, Kansas City	250	16	25·44	0·23		
87	Marty	271	44	44·05	0·15	−0·09	43·96
88	Thomas	327	43	54·21	0·15	+0·02	54·23

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·99 in 1885.
±0·50 in 1887.

Bébé Mound, Douglas County, Kansas. September 14 to September 21, 1885. 35-centimetre theodolite, No. 10. Telescope above ground 16·76 metres. F. D. Granger, observer. June 23 to July 3, 1887. 35-centimetre theodolite, No. 10. Telescope above ground 16·00 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″
95	Thomas	0	00	00·00	±0·06	−0·38	59·62
96	Haskin	33	50	40·97	0·14	+0·28	41·25
92	Simmons	210	31	29·37	0·12	+0·25	29·62
	Carson	245	06	42·15	0·07		
93	Kanwaka	248	07	48·97	0·11	−0·58	48·39
	Blue Mound	262	23	13·90	0·12		
94	Eckman	307	28	52·50	0·13	+0·43	52·93

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·68.

* In 1885. † In 1887.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Continued.

Kanwaka, Douglas County, Kansas. July 28 to August 16, 1887. 35-centimetre theodolite, No. 10. Telescope above ground 17·25 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
99	Simmons	0	00	00·00	±0·08	−0·05	59·95
100	Mabon	49	11	05·88	0·16	+0·03	05·91
101	Elevation	79	56	07·91	0·11	−0·25	07·66
97	Eckman	252	31	27·51	0·11	−0·42	27·09
	Blue Mound	289	36	07·73	0·16		
98	Bébé Mound	301	52	16·80	0·19	+0·69	17·49
	Carson	307	25	14·21	0·07		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·75.

Simmons, Douglas County, Kansas. August 23 to September 14, 1887. 35-centimetre theodolite, No. 10. Telescope above ground 13·72 metres. F. D. Granger, observer.

		°	′	″	″	″	″
104	Kanwaka	0	00	00·00	±0·09	−0·15	59·85
	Carson	35	09	42·78	0·08		
105	Eckman	44	21	21·22	0·11	−0·06	21·16
106	Bébé Mound	84	16	00·62	0·12	−0·08	00·54
102	Mabon	264	30	44·50	0·11	−0·02	44·48
103	Elevation	299	45	06·29	0·12	+0·31	06·60

Probable error of a single observation of a direction (*D.* and R.) = ±0″·66.

Mabon, Osage County, Kansas. September 21 to October 14, 1887. 35-centimetre theodolite, No. 10. Telescope above ground 16·12 metres. F. D. Granger, observer.

		°	′	″	″	″	″
109	Elevation	0	00	00·00	±0·08	−0·17	59·83
110	Kanwaka	51	15	28·09	0·11	+0·35	28·44
111	Simmons	86	35	08·78	0·09	+0·14	08·92
107	Clark	279	01	18·06	0·08	−0·30	17·76
108	Powell	313	07	17·31	0·07	−0·02	17·29

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·52.

Elevation, Shawnee County, Kansas. October 21 to November 3, 1887. 35-centimetre theodolite, No. 10. Telescope above ground 13·72 metres. F. D. Granger, observer.

		°	′	″	″	″	″
114	Mabon	0	00	00·00	±0·09	+0·03	00·03
115	Powell	60	04	24·20	0·11	+0·37	24·57
116	Clark	61	38	23·84	0·08	+0·35	24·19
117	Adams	98	23	29·03	0·14	−0·39	28·64
112	Kanwaka	262	00	29·04	0·12	−0·30	28·74
113	Simmons	301	49	29·69	0·13	−0·06	29·63

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·66.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Continued.

Powell, Shawnee County, Kansas. November 10 to November 15, 1887. 35-centimetre theodolite, No. 10. Telescope above ground 6·10 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
119	Mabon	0 00 00·00	±0·08	−0·03	59·97
120	Clark	109 54 04·98	0·07	+0·34	05·32
121	Adams	177 42 23·08	0·10	+0·18	23·26
118	Elevation	286 57 06·83	0·09	−0·49	06·34

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·50.

Adams, Wabaunsee County, Kansas. July 2 to July 9, 1888. 35-centimetre theodolite, No. 10. Telescope above ground 7·48 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
	Mark	0 00 00·00	±0·09		
122	Elevation	104 17 52·22	0·10	+0·13	52·35
123	Powell	136 44 06·13	0·10	−0·23	05·90
124	Clark	191 57 39·09	0·11	+0·58	39·67
125	Meyer	237 16 28·95	0·11	−0·48	28·47
126	Zean Dale	279 24 43·63	0·09	0·00	43·63

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·59.

Clark, Wabaunsee County, Kansas. August 7 to August 22, 1888. 35-centimetre theodolite, No. 10. Telescope above ground, 13·75 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
130	Adams	0 00 00·00	±0·10	−0·38	59·62
131	Elevation	55 35 09·45	0·11	−0·18	09·27
132	Powell	56 58 09·15	0·09	−0·47	08·68
133	Mabon	92 58 03·90	0·11	+0·71	04·61
127	Reinhard	258 46 18·49	0·10	+0·24	18·73
128	Meyer	281 27 58·88	0·08	−0·10	58·78
129	Zean Dale	302 43 25·24	0·08	+0·18	25·42

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·57.

Meyer, Wabaunsee County, Kansas. August 31 to September 6, 1888. 35-centimetre theodolite, No. 10. Telescope above ground 6·16 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″
136	Zean Dale	0 00 00·00	±0·11	−0·02	00·02
137	Adams	84 10 28·35	0·11	+0·22	28·57
134	Clark	140 19 39·92	0·09	−0·11	39·81
135	Reinhard	281 07 34·57	0·09	−0·13	34·44

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·58.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Continued.

Zean Dale, Riley County, Kansas. September 15 to October 3, 1888. 35-centimetre theodolite, No. 10. Telescope above ground 13·78 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
141	Reinhard	0	00	00·00	±0·08	+0·31	00·31
142	Humboldt	41	02	33·19	0·10	−0·35	32·84
143	Erricssen	84	47	38·04	0·11	+0·49	38·53
138	Adams	249	55	33·38	0·09	−0·11	33·27
139	Clark	285	11	56·85	0·09	−0·23	56·62
140	Meyer	303	36	50·85	0·11	−0·10	50·75

Probable error of a single observation of a direction (*D*. and *R*.) = ± 0″·59.

Reinhard, Morris County, Kansas. October 16 to November 2, 1888. 35-centimetre theodolite, No. 10. Telescope above ground 11·43 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
147	Humboldt	0	00	00·00	±0·08	−0·30	59·70
148	Zean Dale	48	31	56·35	0·09	−0·29	56·06
149	Meyer	93	16	22·40	0·11	−0·32	22·08
150	Clark	109	46	47·33	0·16	+0·72	48·05
144	White City	262	32	48·35	0·14	−0·44	47·91
145	Robbins	321	14	35·19	0·13	−0·14	35·05
146	Erricssen	359	56	23·73	0·13	+0·77	24·50

Probable error of a single observation of a direction (*D*. and *R*.) = ± 0″·72.

White City, Morris County, Kansas. November 10 to November 22, 1888. 35-centimetre theodolite, No. 10. Telescope above ground 6·13 metres. F. D Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
161	Robbins	0	00	00·00	±0·12	−0·46	59·54
162	Reinhard	79	47	11·37	0·12	+0·66	12·03
160	Taylor	307	10	06·41	0·12	−0·21	06·20

Probable error of a single observation of a direction (*D*. and *R*.) = ± 0″·69.

Robbins, Geary County, Kansas. July 26 to August 9, 1889. 35-centimetre theodolite, No. 10. Telescope above ground 5·97 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
163	Humboldt	0	00	00·00	±0·12	+0·19	00·19
164	Reinhard	49	45	34·82	0·10	−0·20	34·62
165	White City	91	16	35·64	0·13	+0·19	35·83
166	Taylor	167	13	09·52	0·14	+0·06	09·58
167	Wilmer	235	00	07·02	0·13	+0·14	07·16
168	Erricssen	306	00	52·27	0·11	−0·39	51·88

Probable error of a single observation of a direction (*D*. and *R*.) = ± 0″·71.

(*b*) *Abstract of resulting horizontal directions at each station, from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Continued.

Humboldt, Geary County, Kansas. August 17 to August 30, 1889. 35-centimetre theodolite, No. 10. Telescope above ground 12·42 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″
153	Robbins	0	00	00·00	±0·09	−0·16	59·84
154	Erricssen	88	24	05·34	0·12	−0·31	05·03
151	Zean Dale	178	05	25·76	0·16	+0·40	26·16
152	Reinhard	268	30	58·15	0·10	+0·07	58·22

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''\cdot 71$.

Erricssen, Riley County, Kansas. September 5 to September 12, 1889. 35-centimetre theodolite, No. 10. Telescope above ground 15·22 metres. F. D. Granger, observer.

		°	′	″	″	″	″
156	Humboldt	0	00	00·00	±0·08	+0·06	00·06
157	Reinhard	0	03	17·58	0·13	+0·47	18·05
158	Robbins	37	36	47·31	0·12	0·00	47·31
159	Wilmer	94	37	27·27	0·09	+0·25	27·52
155	Zean Dale	313	26	26·62	0·11	−0·78	25·84

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''\cdot 64$.

Taylor, Dickinson County, Kansas. October 9 to November 5, 1889. 35-centimetre theodolite, No. 10. Telescope above ground 12·53 metres. F. D. Granger, observer.

		°	′	″	″	″	″
176	Frey	0	00	00·00	±0·07	0·00	00·00
177	Wilmer	36	28	17·72	0·09	−0·18	17·54
178	Robbins	101	19	54·71	0·11	−0·22	54·49
179	White City	152	33	27·83	0·12	+0·65	28·48
174	Iron Mound	301	54	08·41	0·12	−0·67	07·74
175	Vine Creek	348	50	54·83	0·14	+0·42	55·25

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''\cdot 65$.

Wilmer, Dickinson County, Kansas. September 20 to October 1, 1889. 35-centimetre theodolite, No. 10. Telescope above ground 12·19 metres. F. D. Granger, observer.

		°	′	″	″	″	″
172	Frey	0	00	00·00	0·08	+0·61	00·61
173	Vine Creek	38	54	26·28	0·11	−0·08	26·20
169	Erricssen	207	31	50·99	0·13	−0·18	50·81
170	Robbins	259	30	27·94	0·12	−0·54	27·40
171	Taylor	306	51	53·97	0·10	+0·19	54·16

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 0''\cdot 65$.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880, 1882–83–84–85, 1887–88–89–90*—Completed.

Frey, Dickinson County, Kansas. June 14 to June 20, 1890. 35-centimetre theodolite, No. 10. Telescope above ground 6·04 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″		″	″
180	Wilmer	0	00	00·00		−0·36	59·64
181	Taylor	90	23	36·44		+0·06	36·50
182	Iron Mound	183	49	17·60		+0·01	17·61
183	Vine Creek	247	43	11·52		+0·28	11·80

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·54.

Iron Mound, Saline County, Kansas. July 30 to August 13, 1890. 35-centimetre theodolite, No. 10. Telescope above ground 1·74 metres. F. D. Granger, observer. May 16 to May 22, 1896. 30-centimetre theodolite, No. 118. Telescope above ground 1·67 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	North Pole Mound	0	00	00·00	−0·02	59·98	−0·08		59·90
	Salina East Base	13	29	12·12	−0·01	12·11	−0·04		12·07
	Vine Creek	45	39	51·96	+0·02	51·98	+0·33		52·31
187	Frey	78	21	30·32	+0·03	30·35		+0·55	30·90
188	Taylor	106	49	58·94	+0·01	58·95		+0·61	59·56
	Heath	302	47	35·80	−0·01	35·79	−0·02		35·77
	Salina West Base	329	12	45·01	−0·02	44·99	+0·30		45·29
	Thompson	344	26	20·14	−0·03	20·11	−0·48		19·63

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·60.

Vine Creek, Ottawa County, Kansas. June 28 to July 21, 1890. 35-centimetre theodolite, No. 10. Telescope above ground 6·07 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Iron Mound	0	00	00·00	+0·02	00·02	+0·31		00·33
	North Pole Mound	30	57	43·92	+0·03	43·95	−0·67		43·28
	Heath	45	38	34·02	+0·03	34·05	+0·06		34·11
	Thompson	66	55	43·54	+0·01	43·55	+0·29		43·84
184	Wilmer	247	46	44·56	0·00	44·56		−0·57	43·99
185	Frey	276	35	31·59	−0·02	31·57		−0·24	31·33
186	Taylor	288	06	51·69	−0·03	51·66		+0·05	51·71

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·75.

(*c*) *Figure adjustment.*

Observation equations.

No.	Equation
1	$0=-1.07-(2)+(4)-(10)+(11)$
2	$0=-0.59-(3)+(4)-(7)+(8)-(10)+(12)$
3	$0=+0.91-(1)+(2)-(7)+(9)-(11)+(12)$
4	$0=-0.67-(6)+(7)-(12)+(13)-(15)+(16)$
5	$0=-0.09-(13)+(14)+(15)-(18)-(19)+(20)$
6	$0=+0.29-(5)+(6)-(16)+(17)-(27)+(28)$
7	$0=-0.02-(17)+(18)-(20)+(21)-(26)+(27)$
8	$0=+1.24-(21)+(23)-(25)+(26)-(34)+(35)$
9	$0=+0.44-(21)+(22)-(24)+(26)-(32)+(33)$
10	$0=+0.58-(24)+(25)-(31)+(33)-(35)+(36)$
11	$0=-1.69-(30)+(31)-(36)+(37)-(39)+(40)$
12	$0=+0.58-(29)+(30)-(40)+(41)-(51)+(52)$
13	$0=-0.39-(37)+(38)+(39)-(44)-(45)+(46)$
14	$0=+0.43-(43)+(44)-(46)+(47)-(59)+(60)$
15	$0=-1.38-(41)+(42)-(49)+(51)-(57)+(58)$
16	$0=+0.79-(42)+(43)-(56)+(57)-(60)+(62)$
17	$0=-1.21-(49)+(50)-(56)+(58)-(61)+(62)$
18	$0=+0.40-(55)+(56)-(62)+(63)-(65)+(66)$
19	$0=-0.66-(47)+(48)+(59)-(63)-(64)+(65)$
20	$0=-1.73-(54)+(55)-(66)+(67)-(69)+(70)$
21	$0=-2.24-(67)+(68)+(69)-(72)-(73)+(74)$
22	$0=+1.34-(53)+(54)-(70)+(71)-(81)+(82)$
23	$0=-0.09-(71)+(72)-(74)+(75)-(80)+(81)$
24	$0=+1.16-(75)+(76)-(79)+(80)-(83)+(84)$
25	$0=-0.44-(76)+(77)+(83)-(86)-(87)+(88)$
26	$0=-0.55-(78)+(79)-(84)+(85)-(95)+(96)$
27	$0=+1.49-(85)+(86)-(88)+(89)-(94)+(95)$
28	$0=-2.37-(89)+(91)-(93)+(94)-(97)+(98)$
29	$0=-0.85-(89)+(90)-(92)+(94)-(105)+(106)$
30	$0=-0.02-(90)+(91)-(97)+(99)-(104)+(105)$
31	$0=+0.42-(99)+(101)-(103)+(104)-(112)+(113)$
32	$0=+0.26-(99)+(100)-(102)+(104)-(110)+(111)$
33	$0=-0.57-(100)+(101)-(109)+(110)-(112)+(114)$
34	$0=+1.153-(115)+(116)+(118)-(120)-(131)+(132)$
35	$0=-1.34-(107)+(109)-(114)+(116)-(131)+(133)$
36	$0=-1.83-(107)+(108)-(119)+(120)-(132)+(133)$
37	$0=+0.08-(116)+(117)-(122)+(124)-(130)+(131)$
38	$0=+1.79-(115)+(117)+(118)-(121)-(122)+(123)$
39	$0=+1.68-(124)+(125)-(128)+(130)+(134)-(137)$
40	$0=+1.26-(124)+(126)-(129)+(130)-(138)+(139)$
41	$0=-0.70-(125)+(126)-(136)+(137)-(138)+(140)$
42	$0=-1.49-(127)+(129)-(139)+(141)-(148)+(150)$

(*c*) *Figure adjustment*—Continued.

Observation equations—Continued.

No.	
43	$0 = -0.68 \quad -(127)+(128)-(134)+(135)-(149)+(150)$
44	$0 = +0.97 \quad -(141)+(142)-(147)+(148)-(151)+(152)$
45	$0 = -0.38 \quad -(141)+(143)-(146)+(148)-(155)+(157)$
46	$0 = +1.038\,2 -(146)+(147)-(152)+(154)-(156)+(157)$
47	$0 = -0.37 \quad -(153)+(154)-(156)+(158)+(163)-(168)$
48	$0 = +0.79 \quad -(145)+(147)-(152)+(153)-(163)+(164)$
49	$0 = -1.80 \quad -(144)+(145)-(161)+(162)-(164)+(165)$
50	$0 = +0.63 \quad -(158)+(159)-(167)+(168)-(169)+(170)$
51	$0 = -0.49 \quad -(160)+(161)-(165)+(166)-(178)+(179)$
52	$0 = -0.77 \quad -(166)+(167)-(170)+(171)-(177)+(178)$
53	$0 = -0.66 \quad -(171)+(172)-(176)+(177)-(180)+(181)$
54	$0 = -0.25 \quad -(171)+(173)-(175)+(177)-(184)+(186)$
55	$0 = +1.00 \quad -(172)+(173)+(180)-(183)-(184)+(185)$
56	$0 = \quad 1.66 \quad -(174)+(175)-(186)+(188)$
57	$0 = -0.69 \quad -(174)+(176)-(181)+(182)-(187)+(188)$
58	$0 = -7.2 + 2.82(1) - 3.02(2) - 4.49(3) + 2.24(4) + 0.45(10) - 3.10(11) + 2.65(12)$
59	$0 = -7.0 + 4.33(5) - 6.36(6) + 2.03(7) + 0.51(12) - 4.16(13) + 3.65(14) + 2.64(19) - 4.87(20)$
	$+ 2.23(21) + 1.92(26) - 3.55(27) + 1.63(28)$
60	$0 = -3.4 - 0.42(21) + 2.06(22) - 1.64(23) - 1.33(24) - 3.85(25) - 2.52(26) - 2.94(31)$
	$+ 3.22(32) - 0.28(33)$
61	$0 = +2.1 - 2.38(29) + 3.79(30) - 1.41(31) - 0.15(36) + 3.61(37) - 3.46(38) - 1.11(45)$
	$+ 2.40(46) - 1.29(47) - 3.33(50) - 4.35(51) - 1.02(52) - 1.40(59) + 3.08(60) - 1.68(61)$
62	$0 = +1.4 + 2.85(41) - 4.07(42) + 1.22(43) + 2.07(49) - 2.92(50) + 0.85(51) + 0.51(60)$
	$- 4.54(61) - 4.03(62)$
63	$0 = -3.3 - 1.22(42) + 2.19(43) \quad 0.97(44) - 1.29(46) + 6.37(47) - 5.08(48) - 3.66(55)$
	$+ 5.86(56) \quad 2.20(57) - 3.63(64) - 5.39(65) - 1.76(66)$
64	$0 = +16.0 - 4.73(53) + 7.99(54) - 3.26(55) - 0.45(66) + 2.05(67) - 1.60(68) - 2.74(73)$
	$+ 6.41(74) - 3.67(75) - 1.89(80) + 3.26(81) - 1.37(82)$
65	$0 = +5.9 - 1.97(75) + 3.61(76) - 1.64(77) - 4.45(78) - 5.62(79) - 1.17(80) - 1.42(87)$
	$+ 4.75(88) - 3.33(89) - 1.61(94) + 4.75(95) - 3.14(96)$
66	$0 = +1.4 - 0.71(89) + 3.93(90) - 3.22(91) - 2.73(92) + 3.98(93) - 1.25(94) - 1.94(104)$
	$+ 2.16(105) - 0.22(106)$
67	$0 = -3.3 - 0.37(99) + 3.54(100) - 3.17(101) - 2.98(102) + 4.18(103) - 1.20(104) - 1.57(109)$
	$+ 1.69(110) - 0.12(111)$
68	$0 = +2.54 - 0.311(107) + 0.508(108) - 0.197(109) - 0.122(114) + 7.822(115) - 7.70(116)$
	$- 8.72(131) + 9.01(132) - 0.29(133)$
69	$0 = +2.3 - 3.11(107) + 5.08(108) - 1.97(109) - 1.22(114) + 3.88(115) - 2.66(117) - 3.31(122)$
	$+ 4.77(123) - 1.46(124) - 1.37(130) + 4.27(132) - 2.90(133)$
70	$0 = +2.6 - 2.09(124) + 4.42(125) - 2.33(126) - 4.99(128) + 5.42(129) - 0.43(130) - 1.55(138)$
	$+ 6.32(139) - 4.77(140)$
71	$0 = +10.3 - 5.03(127) - 10.45(128) \quad 5.42(129) - 6.32(139) + 7.72(140) - 1.40(141)$
	$- 2.12(148) - 9.23(149) - 7.11(150)$

(c) *Figure adjustment*—Continued.

Observation equations—Completed.

No.

72 $0=+3.071\,3-0.002(141)+0.005(142)-0.002(143)-2.013\,2(146)+2.015\,1(147)-0.002(148)$
$-0.002(155)+2.197\,9(156)-2.195\,9(157)$

73 $0=+8.0-1.28(144)+3.91(145)-2.63(146)-2.74(157)+4.11(158)-1.37(159)-1.60(160)$
$+1.98(161)-0.38(162)-1.65(169)+3.59(170)-1.94(171)-0.98(177)+2.67(178)$
$-1.69(179)$

74 $0=+0.5-2.42(141)+4.62(142)-2.20(143)-2.62(145)+4.48(147)-1.86(148)-1.99(155)$
$+4.72(156)-2.73(158)+3.31(163)-1.78(164)-1.53(168)$

75 $0=+3.3+1.57(171)+4.18(172)-2.61(173)-10.68(175)+13.53(176)-2.85(177)$
$-3.83(184)+14.16(185)-10.33(186)$

76 $0=-6.6-1.57(171)+4.18(172)-2.61(173)-1.31(174)+4.16(176)-2.85(177)-3.83(184)$
$+4.08(185)+7.16(187)-3.88(188)$

77 $0=-4.1+0.20(1)+2.24(3)-2.24(4)+2.03(6)-2.03(7)-1.63(8)+1.63(9)-0.45(10)$
$+0.45(12)+3.65(13)-3.65(14)-1.32(15)+1.32(16)+0.04(17)-0.04(18)-2.64(19)$
$+2.64(20)+0.42(21)-0.42(23)-1.33(24)-1.33(25)-1.92(26)+1.92(27)+2.38(29)$
$-2.38(30)-0.28(31)+0.28(33)-1.14(34)+1.14(35)+0.15(36)-0.15(37)-2.72(39)$
$+2.72(40)+1.22(42)-1.22(43)+0.85(49)-1.87(51)+1.02(52)-3.26(54)+3.26(55)$
$-0.54(57)+0.54(58)-0.51(60)+0.14(62)+0.37(63)-1.76(65)+1.76(66)+1.60(67)$
$-1.60(68)-0.79(69)+0.79(70)-0.45(71)+0.45(72)-2.74(73)+2.74(74)+1.64(76)$
$-1.64(77)+1.17(79)-3.06(80)-1.89(81)-0.69(83)+0.69(84)-0.20(85)+0.20(86)$
$-1.42(87)+1.42(88)-0.71(89)-0.71(91)+2.73(92)-2.73(93)-1.61(94)+1.61(95)$
$-1.81(97)+1.81(98)-0.37(99)-0.37(101)-2.98(102)+2.98(103)-0.22(104)$
$+0.22(106)+0.34(107)-0.46(109)+0.12(111)-2.52(112)+2.52(113)+2.82(116)$
$-2.82(117)-0.09(122)+0.19(124)-0.10(126)+2.18(127)-2.18(129)+2.75(131)$
$+2.75(133)-2.98(138)+2.98(139)+0.19(141)-0.19(143)-2.63(145)-2.63(146)$
$-1.16(148)+1.16(150)-1.99(155)+1.99(157)+1.37(158)-1.37(159)-0.51(164)$
$+0.86(166)-0.86(167)+0.51(168)-1.65(169)+1.65(170)-0.07(171)+0.07(173)$
$+1.97(174)-1.97(175)-0.98(177)+0.98(178)-2.48(184)+2.48(186)+1.16(188)$

Correlate equations.

$(1)=-C_3+2.82C_{58}-0.20C_{77}$
$(2)=-C_1+C_3-3.02C_{58}$
$(3)=-C_2-4.49C_{58}+2.24C_{77}$
$(4)=+C_1+C_2+2.24C_{58}-2.24C_{77}$
$(5)=-C_6+4.33C_{59}$
$(6)=-C_4+C_6-6.36C_{59}+2.03C_{77}$
$(7)=-C_2-C_3+C_4+2.03C_{59}-2.03C_{77}$
$(8)=+C_2-1.63C_{77}$
$(9)=+C_3+1.63C_{77}$
$(10)=-C_1-C_2+0.45C_{58}-0.45C_{77}$
$(11)=+C_1-C_3-3.10C_{58}$
$(12)=+C_2+C_3-C_4+2.65C_{58}+0.51C_{59}+0.45C_{77}$
$(13)=+C_4-C_5-4.16C_{59}+3.65C_{77}$
$(14)=+C_5+3.65C_{59}-3.65C_{77}$
$(15)=-C_4+C_5-1.32C_{77}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

$(16) = + C_4 - C_6 + 1.32C_{77}$
$(17) = + C_6 - C_7 + 0.04C_{77}$
$(18) = - C_5 + C_7 - 0.04C_{77}$
$(19) = - C_5 + 2.64C_{59} - 2.64C_{77}$
$(20) = + C_5 - C_7 - 4.87C_{59} + 2.64C_{77}$
$(21) = + C_7 - C_8 - C_9 + 2.23C_{59} - 0.42C_{60} + 0.42C_{77}$
$(22) = + C_9 + 2.06C_{60}$
$(23) = + C_8 - 1.64C_{60} - 0.42C_{77}$
$(24) = - C_9 - C_{10} - 1.33C_{60} + 1.33C_{77}$
$(25) = - C_8 + C_{10} + 3.85C_{60} - 1.33C_{77}$
$(26) = - C_7 + C_8 + C_9 + 1.92C_{59} - 2.52C_{60} - 1.92C_{77}$
$(27) = - C_6 + C_7 - 3.55C_{59} + 1.92C_{77}$
$(28) = + C_6 + 1.63C_{59}$
$(29) = - C_{12} - 2.38C_{61} + 2.38C_{77}$
$(30) = - C_{11} + C_{12} + 3.79C_{61} - 2.38C_{77}$
$(31) = - C_{10} + C_{11} - 2.94C_{60} - 1.41C_{61} - 0.28C_{77}$
$(32) = - C_9 + 3.22C_{60}$
$(33) = + C_9 + C_{10} - 0.28C_{60} + 0.28C_{77}$
$(34) = - C_8 - 1.14C_{77}$
$(35) = + C_8 - C_{10} + 1.14C_{77}$
$(36) = + C_{10} - C_{11} - 0.15C_{61} + 0.15C_{77}$
$(37) = + C_{11} - C_{13} + 3.61C_{61} - 0.15C_{77}$
$(38) = + C_{13} - 3.46C_{61}$
$(39) = - C_{11} + C_{13} - 2.72C_{77}$
$(40) = + C_{11} - C_{12} + 2.72C_{77}$
$(41) = + C_{12} - C_{15} + 2.85C_{62}$
$(42) = + C_{15} - C_{16} - 4.07C_{62} - 1.22C_{63} + 1.22C_{77}$
$(43) = - C_{14} + C_{16} + 1.22C_{62} + 2.19C_{63} - 1.22C_{77}$
$(44) = - C_{13} + C_{14} - 0.97C_{63}$
$(45) = - C_{13} - 1.11C_{61}$
$(46) = + C_{13} - C_{14} + 2.40C_{61} - 1.29C_{63}$
$(47) = + C_{14} - C_{19} - 1.29C_{61} + 6.37C_{63}$
$(48) = + C_{19} - 5.08C_{63}$
$(49) = - C_{15} - C_{17} + 2.07C_{62} + 0.85C_{77}$
$(50) = + C_{17} - 3.33C_{61} - 2.92C_{62}$
$(51) = - C_{12} + C_{15} + 4.35C_{61} + 0.85C_{62} - 1.87C_{77}$
$(52) = + C_{12} - 1.02C_{61} + 1.02C_{77}$
$(53) = - C_{22} - 4.73C_{64}$
$(54) = - C_{20} + C_{22} + 7.99C_{64} + 3.26C_{77}$
$(55) = - C_{18} + C_{20} - 3.66C_{63} - 3.26C_{64} - 3.26C_{77}$
$(56) = - C_{16} - C_{17} + C_{18} + 5.86C_{63}$
$(57) = - C_{15} + C_{16} - 2.20C_{63} - 0.54C_{77}$
$(58) = + C_{15} + C_{17} + 0.54C_{77}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

$(59) = -C_{14} + C_{19} - 1.40C_{61}$

$(60) = +C_{14} - C_{16} + 3.08C_{61} + 0.51C_{62} - 0.51C_{77}$

$(61) = -C_{17} - 1.68C_{61} - 4.54C_{62}$

$(62) = +C_{16} + C_{17} - C_{18} + 4.03C_{62} + 0.14C_{77}$

$(63) = +C_{18} - C_{19} + 0.37C_{77}$

$(64) = -C_{19} - 3.63C_{63}$

$(65) = -C_{18} + C_{19} + 5.39C_{63} - 1.76C_{77}$

$(66) = +C_{18} - C_{20} - 1.76C_{63} - 0.45C_{64} + 1.76C_{77}$

$(67) = +C_{20} - C_{21} + 2.05C_{64} + 1.60C_{77}$

$(68) = +C_{21} - 1.60C_{64} - 1.60C_{77}$

$(69) = -C_{20} + C_{21} - 0.79C_{77}$

$(70) = +C_{20} - C_{22} + 0.79C_{77}$

$(71) = +C_{22} - C_{23} - 0.45C_{77}$

$(72) = -C_{21} + C_{23} + 0.45C_{77}$

$(73) = -C_{21} - 2.74C_{64} - 2.74C_{77}$

$(74) = +C_{21} - C_{23} + 6.41C_{64} + 2.74C_{77}$

$(75) = +C_{23} - C_{24} - 3.67C_{64} - 1.97C_{65}$

$(76) = +C_{24} - C_{25} + 3.61C_{65} + 1.64C_{77}$

$(77) = +C_{25} - 1.64C_{65} - 1.64C_{77}$

$(78) = -C_{26} - 4.45C_{65}$

$(79) = -C_{24} + C_{26} + 5.62C_{65} + 1.17C_{77}$

$(80) = -C_{23} + C_{24} - 1.89C_{64} - 1.17C_{65} - 3.06C_{77}$

$(81) = -C_{22} + C_{23} + 3.26C_{64} + 1.89C_{77}$

$(82) = +C_{22} - 1.37C_{64}$

$(83) = -C_{24} + C_{25} - 0.69C_{77}$

$(84) = +C_{24} - C_{26} + 0.69C_{77}$

$(85) = +C_{26} - C_{27} - 0.20C_{77}$

$(86) = -C_{25} + C_{27} + 0.20C_{77}$

$(87) = -C_{25} - 1.42C_{65} - 1.42C_{77}$

$(88) = +C_{25} - C_{27} + 4.75C_{65} + 1.42C_{77}$

$(89) = +C_{27} - C_{28} - C_{29} - 3.33C_{65} - 0.71C_{66} + 0.71C_{77}$

$(90) = +C_{29} - C_{30} + 3.93C_{66}$

$(91) = +C_{28} + C_{30} - 3.22C_{66} - 0.71C_{77}$

$(92) = -C_{29} - 2.73C_{66} + 2.73C_{77}$

$(93) = -C_{28} + 3.98C_{66} - 2.73C_{77}$

$(94) = -C_{27} + C_{28} + C_{29} - 1.61C_{65} - 1.25C_{66} - 1.61C_{77}$

$(95) = -C_{26} + C_{27} + 4.75C_{65} + 1.61C_{77}$

$(96) = +C_{26} - 3.14C_{65}$

$(97) = -C_{28} - C_{30} - 1.81C_{77}$

$(98) = +C_{28} + 1.81C_{77}$

$(99) = +C_{30} - C_{31} - C_{32} - 0.37C_{67} + 0.37C_{77}$

$(100) = +C_{32} - C_{33} + 3.54C_{67}$

$(101) = +C_{31} + C_{33} - 3.17C_{67} - 0.37C_{77}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

$(102) = -C_{32} - 2{\cdot}98C_{67} + 2{\cdot}98C_{77}$

$(103) = -C_{31} + 4{\cdot}18C_{67} - 2{\cdot}98C_{77}$

$(104) = -C_{30} + C_{31} + C_{32} - 1{\cdot}94C_{66} - 1{\cdot}20C_{67} - 0{\cdot}22C_{77}$

$(105) = -C_{29} + C_{30} + 2{\cdot}16C_{66}$

$(106) = +C_{29} - 0{\cdot}22C_{66} + 0{\cdot}22C_{77}$

$(107) = -C_{35} - C_{36} - 0{\cdot}311C_{68} - 3{\cdot}11C_{69} + 0{\cdot}34C_{77}$

$(108) = +C_{36} + 0{\cdot}508C_{68} + 5{\cdot}08C_{69}$

$(109) = -C_{33} + C_{35} - 1{\cdot}57C_{67} - 0{\cdot}197C_{68} - 1{\cdot}97C_{69} - 0{\cdot}46C_{77}$

$(110) = -C_{32} + C_{33} + 1{\cdot}69C_{67}$

$(111) = +C_{32} - 0{\cdot}12C_{67} + 0{\cdot}12C_{77}$

$(112) = -C_{31} - C_{33} - 2{\cdot}52C_{77}$

$(113) = +C_{31} + 2{\cdot}52C_{77}$

$(114) = +C_{33} - C_{35} - 0{\cdot}122C_{68} - 1{\cdot}22C_{69}$

$(115) = -C_{34} - C_{38} + 7{\cdot}822C_{68} + 3{\cdot}88C_{69}$

$(116) = +C_{34} + C_{35} - C_{37} - 7{\cdot}70C_{68} + 2{\cdot}82C_{77}$

$(117) = +C_{37} + C_{38} - 2{\cdot}66C_{69} - 2{\cdot}82C_{77}$

$(118) = +C_{34} + C_{38}$

$(119) = -C_{36}$

$(120) = -C_{34} + C_{36}$

$(121) = -C_{38}$

$(122) = -C_{37} - C_{38} - 3{\cdot}31C_{69} - 0{\cdot}09C_{77}$

$(123) = +C_{38} + 4{\cdot}77C_{69}$

$(124) = +C_{37} - C_{39} - C_{40} - 1{\cdot}46C_{69} - 2{\cdot}09C_{70} + 0{\cdot}19C_{77}$

$(125) = +C_{39} - C_{41} + 4{\cdot}42C_{70}$

$(126) = +C_{40} + C_{41} - 2{\cdot}33C_{70} - 0{\cdot}10C_{77}$

$(127) = -C_{42} - C_{43} - 5{\cdot}03C_{71} + 2{\cdot}18C_{77}$

$(128) = -C_{39} + C_{43} - 4{\cdot}99C_{70} + 10{\cdot}45C_{71}$

$(129) = -C_{40} + C_{42} + 5{\cdot}42C_{70} - 5{\cdot}42C_{71} - 2{\cdot}18C_{77}$

$(130) = -C_{37} + C_{39} + C_{40} - 1{\cdot}37C_{69} - 0{\cdot}43C_{70}$

$(131) = -C_{34} - C_{35} + C_{37} - 8{\cdot}72C_{68} - 2{\cdot}75C_{77}$

$(132) = +C_{34} - C_{36} + 9{\cdot}01C_{68} + 4{\cdot}27C_{69}$

$(133) = +C_{35} + C_{36} - 0{\cdot}29C_{68} - 2{\cdot}90C_{69} + 2{\cdot}75C_{77}$

$(134) = +C_{39} - C_{43}$

$(135) = +C_{43}$

$(136) = -C_{41}$

$(137) = -C_{39} + C_{41}$

$(138) = -C_{40} - C_{41} - 1{\cdot}55C_{70} - 2{\cdot}98C_{77}$

$(139) = +C_{40} - C_{42} + 6{\cdot}32C_{70} - 6{\cdot}32C_{71} + 2{\cdot}98C_{77}$

$(140) = +C_{41} - 4{\cdot}77C_{70} + 7{\cdot}72C_{71}$

$(141) = +C_{42} - C_{44} - C_{45} - 1{\cdot}40C_{71} - 0{\cdot}002C_{72} - 2{\cdot}42C_{74} + 0{\cdot}19C_{77}$

$(142) = +C_{44} + 0{\cdot}005C_{72} + 4{\cdot}62C_{74}$

$(143) = +C_{45} - 0{\cdot}002C_{72} - 2{\cdot}20C_{74} - 0{\cdot}19C_{77}$

$(144) = -C_{49} - 1{\cdot}28C_{73}$

$(145) = -C_{48} + C_{49} + 3{\cdot}91C_{73} - 2{\cdot}62C_{74} + 2{\cdot}63C_{77}$

(*c*) *Figure adjustment*—Continued.

Correlate equations—Completed.

$(146) = -C_{45} - C_{46} - 2.013\,2C_{72} - 2.63C_{73} - 2.63C_{77}$
$(147) = -C_{44} + C_{46} + C_{48} + 2.015\,1C_{72} + 4.48C_{74}$
$(148) = -C_{42} + C_{44} + C_{45} - 2.12C_{71} - 0.002C_{72} - 1.86C_{74} - 1.16C_{77}$
$(149) = -C_{43} + 9.23C_{71}$
$(150) = +C_{42} + C_{43} - 7.11C_{71} + 1.16C_{77}$
$(151) = -C_{44}$
$(152) = +C_{44} - C_{46} - C_{48}$
$(153) = -C_{47} + C_{48}$
$(154) = +C_{46} + C_{47}$
$(155) = -C_{45} - 0.002C_{72} - 1.99C_{74} - 1.99C_{77}$
$(156) = -C_{46} - C_{47} + 2.197\,9C_{72} + 4.72C_{74}$
$(157) = +C_{45} + C_{46} - 2.195\,9C_{72} - 2.74C_{73} + 1.99C_{77}$
$(158) = +C_{47} - C_{50} + 4.11C_{73} - 2.73C_{74} + 1.37C_{77}$
$(159) = +C_{50} - 1.37C_{73} - 1.37C_{77}$
$(160) = -C_{51} - 1.60C_{73}$
$(161) = -C_{49} + C_{51} + 1.98C_{73}$
$(162) = +C_{49} - 0.38C_{73}$
$(163) = +C_{47} - C_{48} + 3.31C_{74}$
$(164) = +C_{48} - C_{49} - 1.78C_{74} - 0.51C_{77}$
$(165) = +C_{49} - C_{51}$
$(166) = +C_{51} - C_{52} + 0.86C_{77}$
$(167) = -C_{50} + C_{52} - 0.86C_{77}$
$(168) = -C_{47} + C_{50} - 1.53C_{74} + 0.51C_{77}$
$(169) = -C_{50} - 1.65C_{73} - 1.65C_{77}$
$(170) = +C_{50} - C_{52} + 3.59C_{73} + 1.65C_{77}$
$(171) = +C_{52} - C_{53} - C_{54} - 1.94C_{73} - 1.57C_{75} - 1.57C_{76} - 0.07C_{77}$
$(172) = +C_{53} - C_{55} + 4.18C_{75} + 4.18C_{76}$
$(173) = +C_{54} + C_{55} - 2.61C_{75} - 2.61C_{76} + 0.07C_{77}$
$(174) = -C_{56} - C_{57} - 1.31C_{76} + 1.97C_{77}$
$(175) = -C_{54} + C_{56} - 10.68C_{75} - 1.97C_{77}$
$(176) = -C_{53} + C_{57} + 13.53C_{75} + 4.16C_{76}$
$(177) = -C_{52} + C_{53} + C_{54} - 0.98C_{73} - 2.85C_{75} - 2.85C_{76} - 0.98C_{77}$
$(178) = -C_{51} + C_{52} + 2.67C_{73} + 0.98C_{77}$
$(179) = +C_{51} - 1.69C_{73}$
$(180) = -C_{53} + C_{55}$
$(181) = +C_{53} - C_{57}$
$(182) = +C_{57}$
$(183) = -C_{55}$
$(184) = -C_{54} - C_{55} - 3.83C_{75} - 3.83C_{76} - 2.48C_{77}$
$(185) = +C_{55} + 14.16C_{75} + 4.08C_{76}$
$(186) = +C_{54} - C_{56} - 10.33C_{75} + 2.48C_{77}$
$(187) = -C_{57} + 7.16C_{76}$
$(188) = +C_{56} + C_{57} - 3.88C_{76} + 1.16C_{77}$

(*c*) *Figure adjustment*—Continued.

Normal equations.

		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
1	0 = − 1·07	+4	+2	−2															
2	= − 0·59		+6	+2	−2														
3	= + 0·91			+6	−2														
4	= − 0·67				+6	−2	−2												
5	= − 0·09	...	..	...	...	+6	...	−2	...	...	...	...	...	...	...	...	...	...	...
6	= + 0·29						+6	−2											
7	= − 0·02							+6	−2	−2									
8	= + 1·24								+6	+2	−2								
9	= + 0·44									+6	+2								
10	= + 0·58	...	...	. .	...	...	...	...	...	...	+6	−2	...	...	...	...	...	...	...
11	= − 1·69											+6	−2	−2					
12	= + 0·58												+6			−2			
13	= − 0·39													+6	−2				
14	= + 0·43														+6		−2		
15	= − 1·38	. .	...	...	...	...	...	...	..	...	...	...	...	...	...	+6	−2	+2	...
16	= + 0·79																+6	+2	−2
17	= − 1·21																	+6	−2
18	= + 0·40																		+6

Normal equations—Continued.

		C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{39}
14	0 = + 0·43	−2																				
18	= + 0·40	−2	−2																			
19	= − 0·66	+6																				
20	= − 1·73		+6	−2	−2																	
21	= − 2·24	...	...	+6	...	−2	...	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	= + 1·34				+6	−2																
23	= − 0·09					+6	−2															
24	= + 1·16						+6	−2	−2													
25	= − 0·44							+6		−2												
26	= − 0·55	. .	...	...	...	...	...	. .	+6	−2	...	...	...	...	...	...	...	...	...	...	...	...
27	= + 1·49									+6	−2	−2										
28	= − 2·37										+6	+2	+2									
29	= − 0·85											+6	−2									
30	= − 0·02												+6	−2	−2							
31	= + 0·42	. .	...	..	...	...	...	...	...	...	...	...	...	+6	+2	+2	...	...	...	...	...	...
32	= + 0·26														+6	−2						
33	= − 0·57															+6		−2				
34	= + 1·153																+6	+2	−2	−2	+2	
35	= − 1·34																	+6	+2	−2		
36	= − 1·83	...	...	. .	...	...	. .	...	...	...	...	...	...	...	...	...	...	...	+6	...	...	...
37	= + 0·08																			+6	+2	−2
38	= + 1·79																				+6	
39	= + 1·68																					+6

(*c*) *Figure adjustment*—Continued.

Normal equations—Continued.

		C_{40}	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}	C_{47}	C_{48}	C_{49}	C_{50}	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}	C_{56}	C_{57}
38	0=+ 0·08	−2																	
39	=+ 1·68	+2	−2		−2														
40	=+ 1·26	+6	+2	−2															
41	=− 0·70		+6																
42	=− 1·49	...	...	+6	+2	−2	−2	...	...	...	...	...	...	...	...	...	..	...	..
43	=− 0·68				+6														
44	=+ 0·97					+6	+2	−2		−2									
45	=− 0·38						+6	+2											
46	=+ 1·038 2							+6	+2	+2									
47	=− 0·37	...	...	...	...	...	...	...	+6	−2	...	−2	...	...	...	...	...	...	...
48	=+ 0·79									+6	−2								
49	=− 1·80										+6		−2						
50	=+ 0·63											+6		−2					
51	=− 0·49												+6	−2					
52	=− 0·77	...	...	...	...	...	...	...	...	...	...	...	...	+6	−2	−2	...	...	..
53	=− 0·66														+6	+2	−2		2
54	=+ 0·25															+6	+2	−2	
55	=+ 1·00																+6		
56	=− 1·66																	+4	+2
57	=− 0·69	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...	+6

Normal equations—Continued.

		C_{58}	C_{59}	C_{60}	C_{61}	C_{62}	C_{63}	C_{64}	C_{65}	C_{66}	C_{67}	C_{68}
1	0=− 1·07	+1·71										
2	=− 0·59	+8·93	−1·52									
3	=+ 0·91	−0·09	−1·52									
4	=− 0·67	−2·65	+3·72									
5	=− 0·09	......	+0·30	......	......	...	......	......	.....	......	......	......
6	=+ 0·29		−5·51									
7	=− 0·02		+1·63	+2·10								
8	=+ 1·24		−0·31	−7·59								
9	=+ 0·44		−0·31	−2·21								
10	=+ 0·58	......	......	+7·84	+1·26	......	......	......	......	......	......	......
11	=− 1·69			−2·94	−1·44							
12	=+ 0·58				+0·80	+2·00						
13	=− 0·39				−3·56		−0·32					
14	=+ 0·43				+0·79	−0·71	+4·50					
15	=− 1·38	......	......	......	+4·35	−8·14	+0·98	......	......	......	......	......
16	=+ 0·79				−3·08	+8·81	−4·65					
17	=− 1·21				−1·65	+3·58	−5·86					
18	=+ 0·40					−4·03	+2·37	+2·81				
19	=− 0·66				−0·11		−2·43					
20	=− 1·73	......	......	......	......	......	−1·90	−8·75	......	......	......	......
21	=− 2·24							+5·50				
22	=+ 1·34							+8·09				
23	=− 0·09							−4·93	−0·80			
24	=+ 1·16							+1·78	−1·21			
25	=− 0·44	......	......	......	......	.....	......	......	+0·92	......	......	......
26	=− 0·55								+2·18			
27	=+ 1·49								−1·72	+0·54		
28	=− 2·37								+1·72	−7·74		
29	=− 0·85								+1·72	+3·74		
30	=− 0·02	......	......	......	......	......	......	......	......	−3·05	+0·83	......
31	=+ 0·42									−1·94	−8·18	

(c) *Figure adjustment*—Continued.

Normal equations—Continued.

		C_{58}	C_{59}	C_{60}	C_{61}	C_{62}	C_{63}	C_{64}	C_{65}	C_{66}	C_{67}	C_{68}
32	=+ 0·26									−1·94	+3·88	
33	=− 0·57										−3·45	+0·075
34	=+ 1·153											+2·208
35	=− 1·34	......	......	......	......	......	......	......	......	......	−1·57	+0·966
36	=− 1·83											−8·481
37	=+ 0·08											−1·02
38	=+ 1·79											−7·822
58	=− 7·2	+59·09	+ 1·35									
59	=− 7·0	......	+148·81	− 5·78	......	......	......	......	......	......	......	......
60	=− 3·4			+49·14	+ 4·145							
61	=+ 2·1				+101·02	+22·62	− 11·31					
62	=+ 1·4					+76·82	+ 7·64					
63	=− 3·3						+173·17	+ 12·72				
64	=+16·0	......	......	......	......	......	......	+181·95	+ 9·44	......	......	......
65	=+ 5·9								+143·035	+ 4·37		
66	=+ 1·4									+59·64	+ 2·33	
67	=− 3·3										+55·84	+ 0·31
68	=+ 2·54											+278·185

Normal equations—Continued.

		C_{69}	C_{70}	C_{71}	C_{72}	C_{73}	C_{74}	C_{75}	C_{76}	C_{77}
1	0=− 1·07									− 1·79
2	=− 0·59									− 3·18
3	=+ 0·91									+ 3·91
4	=− 0·67									+ 1·78
5	=− 0·09	......	......	......	......	......	......	......	......	− 3·30
6	=+ 0·29									− 1·17
7	=− 0·02									+ 1·54
8	=+ 1·24									+ 0·85
9	=+ 0·44									− 3·39
10	=+ 0·58	......	......	......	......	......	......	......	......	− 3·09
11	=− 1·69									+ 7·24
12	=+ 0·58									− 4·59
13	=− 0·39									− 2·57
14	=+ 0·43									+ 0·71
15	=− 1·38	......	......	......	......	......	......	......	......	− 0·42
16	=+ 0·79									− 2·33
17	=− 1·21									− 0·17
18	=+ 0·40									+ 7·01
19	=− 0·66									− 2·13
20	=− 1·73	......	......	......	......	......	......	......	......	− 5·10
21	=− 2·24									+ 1·04
22	=+ 1·34									+ 0·13
23	=− 0·09									+ 3·11
24	=+ 1·16									− 1·21
25	=− 0·44	......	......	......	......	......	......	......	......	− 1·33
26	=− 0·55									− 1·33
27	=+ 1·49									+ 2·91
28	=− 2·37									+ 3·32
29	=− 0·85									− 4·83
30	=− 0·02	......	......	......	......	......	......	......	......	+ 1·69
31	=+ 0·42									+ 7·06
32	=+ 0·26									− 3·45
33	=− 0·57	+0·75								+ 2·61

(*c*) *Figure adjustment*—Completed.

Normal equations—Completed.

		C_{69}	C_{70}	C_{71}	C_{72}	C_{73}	C_{74}	C_{75}	C_{76}	C_{77}
34	= + 1.153	+0.39								+ 5.57
35	= − 1.34	−0.54	......	......	......	......	......	......	......	+ 7.52
36	= − 1.83	+1.02								+ 2.41
37	= + 0.08	+0.56	− 1.66							− 8.11
38	= + 1.79	+1.54								− 2.73
39	= + 1.68	+0.09	+11.07	−10.45						− 0.19
40	= + 1.26	+0.09	+ 1.78	− 0.90	......	......	......	......	......	+ 7.85
41	= − 0.70		− 9.97	+ 7.72						+ 2.88
42	= − 1.49		− 0.90	− 0.46			−0.56			− 4.83
43	= − 0.68		− 4.99	− 0.86						− 1.02
44	= + 0.97			− 0.72	−2.010		+0.70			− 1.35
45	= − 0.38	......	......	− 0.72	−0.183	−0.11	+0.35	......	......	+ 5.07
46	= + 1.038 2				−0.365 5	−0.11	−0.24			+ 4.62
47	= − 0.37				−2.198	+4.11	−2.61			+ 0.86
48	= + 0.79				+2.015	−3.91	+2.01			− 3.14
49	= − 1.80					+2.83	−0.84			+ 3.14
50	= + 0.63	......	......	......	......	−0.24	+1.20	......	......	+ 1.93
51	= − 0.49					−0.78				− 0.12
52	= − 0.77					−1.88		+ 1.28	+1.28	− 1.48
53	= − 0.66					+0.96		−10.63	−1.26	− 0.91
54	= + 0.25					+0.96		+ 0.29	−0.06	+ 6.09
55	= + 1.00	......	......	......	......	......	......	+11.20	+1.12	+ 2.55
56	= − 1.66							− 0.35	−2.57	− 5.26
57	= − 0.69							+13.53	−5.57	− 0.81
58	= − 7.2									− 13.52
59	= − 7.0									− 74.70
60	= − 3.4	......	......	......	......	......	......	......	......	− 0.79
61	= + 2.1									− 25.60
62	= + 1.4									− 5.98
63	= − 3.3									− 3.62
64	= +16.0									+ 78.74
65	= + 5.9	......	......	......	......	......	......	......	......	+ 35.40
66	= + 1.4									− 14.15
67	= − 3.3	+ 3.09								− 19.33
68	= + 2.54	+ 73.75								+ 1.45
69	= + 2.3	+127.34	+ 3.64							− 0.60
70	= + 2.6	......	+148.89	−158.29	......	......	......	......	......	+ 11.47
71	= +10.3			+405.61	+ 0.007		+ 7.33			− 24.04
72	= + 3.071 3				+17.766	+11.311	+ 19.442			+ 0.932
73	= + 8.0					+87.07	− 21.46	+ 5.84	+ 5.84	+ 31.62
74	= + 0.5						+112.59			− 4.43
75	= + 3.3	......	......	......	......	......	......	+653.88	+163.60	+ 7.64
76	= − 6.6								+151.53	+ 5.14
77	= − 4.1									+367.75

Resulting values of correlates.

C_1 = +0·280	C_{21} = +0·702	C_{41} = −0·018	C_{61} = +0·023 5
C_2 = −0·097	C_{22} = +0·182	C_{42} = +0·378	C_{62} = −0·012 4
C_3 = −0·040	C_{23} = +0·102	C_{43} = −0·129	C_{63} = +0·049 1
C_4 = +0·090	C_{24} = −0·081	C_{44} = −0·399	C_{64} = −0·138 1
C_5 = +0·081	C_{25} = +0·026	C_{45} = +0·534	C_{65} = −0·069 5
C_6 = +0·081	C_{26} = +0·060	C_{46} = −0·959	C_{66} = +0·055 9
C_7 = −0·059	C_{27} = −0·166	C_{47} = +0·647	C_{67} = +0·072 6
C_8 = −0·241	C_{28} = +0·493	C_{48} = +0·487	C_{68} = −0·009 93
C_9 = +0·178	C_{29} = −0·094	C_{49} = +0·610	C_{69} = −0·009 7
C_{10} = −0·246	C_{30} = −0·274	C_{50} = +0·219	C_{70} = −0·060 7
C_{11} = +0·236	C_{31} = −0·342	C_{51} = +0·422	C_{71} = −0·048 2
C_{12} = +0·118	C_{32} = +0·136	C_{52} = +0·456	C_{72} = −0·138 6
C_{13} = +0·221	C_{33} = +0·363	C_{53} = +0·077	C_{73} = −0·135 3
C_{14} = +0·038	C_{34} = −0·309	C_{54} = +0·348	C_{74} = +0·010 4
C_{15} = +0·147	C_{35} = +0·342	C_{55} = −0·282	C_{75} = −0·019 7
C_{16} = +0·018	C_{36} = +0·031	C_{56} = +0·778	C_{76} = +0·079 0
C_{17} = +0·282	C_{37} = +0·077	C_{57} = +0·014	C_{77} = +0·111 8
C_{18} = +0·212	C_{38} = −0·181	C_{58} = +0·155 6	
C_{19} = +0·253	C_{39} = −0·235	C_{59} = +0·105 6	
C_{20} = +0·563	C_{40} = −0·109	C_{60} = +0·108 1	

Resulting corrections to angular directions.

″	″	″	″
(1) = +0·501	(48) = +0·004	(95) = −0·376	(142) = −0·352
(2) = −0·790	(49) = −0·360	(96) = +0·278	(143) = +0·490
(3) = −0·352	(50) = +0·240	(97) = −0·421	(144) = −0·457
(4) = +0·282	(51) = −0·089	(98) = +0·695	(145) = −0·139
(5) = +0·376	(52) = +0·208	(99) = −0·054	(146) = +0·766
(6) = −0·454	(53) = +0·471	(100) = +0·030	(147) = −0·305
(7) = +0·214	(54) = −1·120	(101) = −0·251	(148) = −0·290
(8) = −0·279	(55) = +0·257	(102) = −0·019	(149) = −0·316
(9) = +0·142	(56) = +0·200	(103) = +0·312	(150) = +0·722
(10) = −0·164	(57) = −0·297	(104) = −0·152	(151) = +0·399
(11) = −0·162	(58) = +0·489	(105) = −0·059	(152) = +0·073
(12) = +0·290	(59) = +0·182	(106) = −0·081	(153) = −0·160
(13) = −0·022	(60) = +0·029	(107) = −0·302	(154) = −0·312
(14) = +0·058	(61) = −0·265	(108) = −0·023	(155) = −0·777
(15) = −0·157	(62) = +0·054	(109) = −0·165	(156) = +0·056
(16) = +0·157	(63) = 0·000	(110) = +0·350	(157) = +0·472
(17) = +0·144	(64) = −0·431	(111) = +0·140	(158) = −0·003
(18) = −0·144	(65) = +0·109	(112) = −0·303	(159) = +0·251
(19) = −0·097	(66) = −0·178	(113) = −0·060	(160) = −0·206
(20) = −0·079	(67) = −0·243	(114) = +0·034	(161) = −0·456
(21) = +0·241	(68) = +0·744	(115) = +0·374	(162) = +0·661
(22) = +0·400	(69) = +0·052	(116) = +0·347	(163) = +0·194

Resulting corrections to angular directions—Completed.

″	″	″	″
(23) = −0·465	(70) = +0·468	(117) = −0·393	(164) = −0·199
(24) = +0·074	(71) = +0·030	(118) = −0·490	(165) = +0·188
(25) = +0·261	(72) = −0·550	(119) = −0·031	(166) = +0·062
(26) = −0·288	(73) = −0·630	(120) = +0·340	(167) = +0·141
(27) = −0·300	(74) = +0·021	(121) = +0·181	(168) = −0·387
(28) = +0·253	(75) = +0·827	(122) = +0·126	(169) = −0·180
(29) = +0·092	(76) = −0·175	(123) = −0·227	(170) = −0·539
(30) = −0·295	(77) = −0·043	(124) = +0·583	(171) = +0·192
(31) = +0·101	(78) = +0·249	(125) = −0·485	(172) = +0·607
(32) = +0·169	(79) = −0·119	(126) = +0·003	(173) = −0·081
(33) = −0·067	(80) = −0·183	(127) = +0·237	(174) = −0·675
(34) = +0·114	(81) = −0·319	(128) = −0·095	(175) = +0·420
(35) = +0·132	(82) = +0·371	(129) = +0·175	(176) = −0·001
(36) = −0·469	(83) = +0·030	(130) = −0·382	(177) = −0·177
(37) = +0·083	(84) = −0·064	(131) = −0·176	(178(= −0·217
(38) = +0·140	(85) = +0·204	(132) = −0·470	(179) = +0·651
(39) = −0·319	(86) = −0·170	(133) = +0·711	(180) = −0·359
(40) = +0·422	(87) = −0·086	(134) = −0·106	(181) = +0·063
(41) = −0·064	(88) = +0·021	(135) = −0·129	(182) = +0·014
(42) = +0·255	(89) = −0·295	(136) = +0·018	(183) = +0·282
(43) = −0·063	(90) = +0·400	(137) = +0·217	(184) = −0·570
(44) = −0·231	(91) = −0·040	(138) = −0·112	(185) = −0·239
(45) = −0·247	(92) = +0·246	(139) = −0·233	(186) = +0·051
(46) = +0·176	(93) = −0·576	(140) = −0·100	(187) = +0·552
(47) = +0·068	(94) = +0·427	(141) = +0·306	(188) = +0·615

(*d*) *Adjusted triangles, Missouri and Kansas.*

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
1	Schnackenberg	52	13	57·56	+0·42	57·98	0·55	4·439 731 0	27 525·23
	Hubbard	43	08	57·77	−0·35	57·42	0·55	4·376 819 4	23 813·29
	Hughes	84	37	06·76	−0·50	06·26	0·56	4·539 908 3	34 666·37
				02·09			1·66		
2	Heard	43	55	02·29	0·00	02·29	0·70	4·439 731 0	27 525·23
	Hubbard	86	18	08·77	+0·28	09·05	0·71	4·597 706 3	39 601·01
	Hughes	49	46	49·98	+0·79	50·77	0·70	4·481 464 2	30 301·50
				01·04			2·11		
3	Heard	78	03	56·20	+0·45	56·65	0·60	4·539 908 3	34 666·37
	Hubbard	43	09	11·00	+0·63	11·63	0·61	4·384 422 8	24 233·87
	Schnackenberg	58	46	54·03	−0·49	53·54	0·61	4·481 464 2	30 301·50
				01·23			1·82		

(*d*) *Adjusted triangles, Missouri and Kansas*—Continued.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
4	Schnackenberg	111	00	51 ·59	−0 ·07	51 ·52	0 ·45	4 ·597 706 3	39 601 ·01
	Heard	34	08	53 ·91	+0 ·45	54 ·36	0 ·46	4 ·376 819 5	23 813 ·30
	Hughes	34	50	16 ·78	−1 ·29	15 ·49	0 ·46	4 ·384 422 9	24 233. 88
				02 ·28			1 ·37		
5	Kendrick	57	50	15 ·10	+0 ·31	15 ·41	0 ·41	4 ·384 422 8	24 233 ·87
	Heard	76	13	14 ·27	−0 ·31	13 ·96	0 ·41	4 ·444 091 7	27 803 ·00
	Schnackenberg	45	56	31 ·19	+0 ·67	31 ·86	0 ·41	4 ·313 284 0	20 572 ·36
				00 ·56			1 ·23		
6	Knob Noster	38	32	57 ·60	+0 ·02	57 ·62	0 ·27	4 ·313 284 0	20 572 ·36
	Heard	29	57	21 ·31	+0 ·08	21 ·39	0 ·27	4 ·217 055 5	16 483 ·73
	Kendrick	111	29	41 ·80	−0 ·01	41 ·79	0 ·26	4 ·487 358 6	30 715 ·57
				00 ·71			0 ·80		
7	High Point Tebo	52	23	44 ·11	+0 ·55	44 ·66	0 ·35	4 ·444 091 7	27 803 ·00
	Kendrick	101	42	03 ·23	−0 ·01	03 ·22	0 ·36	4 ·536 113 5	34 364 ·78
	Schnackenberg	25	54	14 ·01	−0 ·83	13 ·18	0 ·35	4 ·185 573 3	15 331 ·10
				01 ·35			1 ·06		
8	High Point Tebo	47	37	45 ·97	−0 ·01	45 ·96	0 ·21	4 ·217 055 5	16 483 ·73
	Knob Noster	43	24	14 ·78	+0 ·32	15 ·10	0 ·21	4 ·185 573 3	15 331 ·10
	Kendrick	88	57	59 ·87	−0 ·29	59 ·58	0 ·22	4 ·348 457 5	22 307 ·84
				00 ·62			0 ·64		
9	Normal	61	26	26 ·69	+0 ·02	26 ·71	0 ·30	4 ·348 457 5	22 307 ·84
	Knob Noster	78	42	43 ·55	−0 ·71	42 ·84	0 ·30	4 ·396 319 8	24 906 ·91
	High Point Tebo	39	50	51 ·90	−0 ·55	51 ·35	0 ·30	4 ·211 489 8	16 273 ·83
				02 ·14			0 ·90		
10	Caldwell	49	16	36 ·11	−0 ·24	35 ·87	0 ·30	4 ·348 457 5	22 307 ·84
	Knob Noster	33	03	28 ·71	+0 ·16	28 ·87	0 ·30	4 ·205 648 6	16 056 ·41
	High Point Tebo	97	39	56 ·52	−0 ·36	56 ·16	0 ·30	4 ·464 965 9	29 171 ·98
				01 ·34			0 ·90		
11	Caldwell	82	27	31 ·93	−0 ·17	31 ·76	0 ·28	4 ·396 319 8	24 906 ·91
	Normal	39	43	24 ·89	−0 ·60	24 ·29	0 ·29	4 ·205 648 5	16 056 ·41
	High Point Tebo	57	49	04 ·62	+0 ·19	04 ·81	0 ·29	4 ·327 647 5	21 264 ·12
				01 ·44			0 ·86		
12	Normal	101	09	51 ·58	−0 ·58	51 ·00	0 ·28	4 ·464 965 9	29 171 ·98
	Knob Noster	45	39	14 ·84	−0 ·87	13 ·97	0 ·29	4 ·327 647 5	21 264 ·12
	Caldwell	33	10	55 ·82	+0 ·07	55 ·89	0 ·29	4 ·211 489 9	16 273 ·84
				02 ·24			0 ·86		

(*d*) *Adjusted triangles, Missouri and Kansas*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
13	Baker	37	43	19·79	+0·74	20·53	0·52	4·327 647 5	21 264·12
	Normal	86	02	28·77	+0·55	29·32	0·52	4·539 976 6	34 671·82
	Caldwell	56	14	11·31	+0·40	11·71	0·52	4·460 791 7	28 892·94
				59·87			1·56		
14	Hutton Mound	64	14	45·10	+0·30	45·40	0·72	4·539 976 6	34 671·82
	Baker	74	17	51·88	−0·49	51·39	0·72	4·568 894 5	37 059·07
	Caldwell	41	27	25·76	−0·39	25·37	0·72	4·406 307 4	25 486·34
				02·74			2·16		
15	Chapel Hill	62	07	55·12	+0·42	55·54	0·42	4·460 791 7	28 892·94
	Normal	31	20	31·34	+0·06	31·40	0·42	4·230 450 2	17 000·05
	Baker	86	31	34·40	−0·09	34·31	0·41	4·513 527 5	32 623·27
				00·86			1·25		
16	Thornton	56	23	38·35	−0·15	38·20	0·23	4·230 450 2	17 000·05
	Chapel Hill	58	26	56·61	−0·11	56·50	0·23	4·240 405 5	17 394·24
	Baker	65	09	26·15	−0·17	25·98	0·22	4·267 706 2	18 522·78
				01·11			0·68		
17	Fulton	75	33	22·57	+0·79	23·36	0·32	4·406 307 4	25 486·34
	Baker	36	25	16·29	+0·32	16·61	0·31	4·193 834 7	15 625·53
	Hutton Mound	68	01	20·70	+0·27	20·97	0·31	4·387 490 0	24 405·63
				59·56			0·94		
18	Thornton	51	26	46·51	−0·29	46·22	0·37	4·406 307 4	25 486·34
	Baker	96	17	47·78	0·00	47·78	0·38	4·510 460 7	32 393·71
	Hutton Mound	32	15	27·45	−0·33	27·12	0·37	4·240 405 4	17 394·24
				01·74			1·12		
19	Thornton	76	18	04·48	+0·03	04·51	0·31	4·387 490 0	24 405·63
	Baker	59	52	31·49	−0·32	31·17	0·31	4·337 006 3	21 727·32
	Fulton	43	49	25·75	−0·50	25·25	0·31	4·240 405 5	17 394·24
				01·72			0·93		
20	Fulton	119	22	48·32	+0·29	48·61	0·25	4·510 460 7	32 393·71
	Thornton	24	51	17·97	+0·32	18·29	0·25	4·193 834 6	15 625·53
	Hutton Mound	35	45	53·25	+0·60	53·85	0·25	4·337 006 2	21 727·32
				59·54			0·75		
21	Bowler	50	05	23·86	−0·28	23·58	0·26	4·337 006 3	21 727·32
	Thornton	100	00	33·28	−0·06	33·22	0·25	4·445 521 3	27 894·67
	Fulton	29	54	04·03	−0·06	03·97	0·26	4·149 850 2	14 120·50
				01·17			0·77		

(*d*) *Adjusted triangles, Missouri and Kansas*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres
		°	′	″	″	″	″		
22	Bowler	30	10	26·79	+0·54	27·33	0·18	4·267 706 2	18 522·78
	Chapel Hill	22	31	49·19	−0·06	49·13	0·18	4·149 850 1	14 120·50
	Thornton	127	17	43·89	+0·18	44·07	0·17	4·467 108 5	29 316·26
				59·87			0·53		
23	Berry	69	19	14·95	+0·42	15·37	0·37	4·445 521 3	27 894·67
	Bowler	77	52	22·13	−0·07	22·06	0·38	4·464 642 0	29 150·23
	Fulton	32	48	22·31	+1·38	23·69	0·37	4·208 285 4	16 154·20
				59·39			1·12		
24	Marty	37	32	43·27	+0·65	43·92	0·29	4·208 285 4	16 154·20
	Bowler	52	48	31·23	+0·99	32·22	0·29	4·324 642 8	21 117·51
	Berry	89	38	44·13	+0·60	44·73	0·29	4·423 381 4	26 508·27
				58·63			0·87		
25	Haskin	57	01	28·22	+0·69	28·91	0·34	4·464 642 0	29 150·23
	Berry	98	58	37·36	−0·44	36·92	0·35	4·535 577 3	34 322·37
	Fulton	23	59	56·79	−1·59	55·20	0·34	4·150 218 6	14 132·49
				02·37			1·03		
26	Haskin	48	04	44·95	−0·14	44·81	0·25	4·324 642 8	21 117·51
	Marty	29	51	52·14	+0·81	52·95	0·25	4·150 218 6	14 132·49
	Berry	102	03	23·56	−0·58	22·98	0·24	4·443 344 1	27 755·18
				00·65			0·74		
27	Thomas	72	04	58·79	−0·10	58·69	0·43	4·443 344 1	27 755·18
	Marty	46	54	35·94	−1·00	34·94	0·44	4·328 421 6	21 302·06
	Haskin	61	00	27·74	−0·06	27·68	0·44	4·406 785 3	25 514·39
				02·47			1·31		
28	Eckman	55	59	10·16	+0·11	10·27	0·50	4·406 785 3	25 514·39
	Marty	52	09	14·08	+0·13	14·21	0·50	4·385 722 8	24 306·52
	Thomas	71	51	36·82	+0·20	37·02	0·50	4·466 142 9	29 251·15
				01·06			1·50		
29	Bébé Mound	33	50	40·97	+0·65	41·62	0·25	4·328 421 6	21 302·06
	Thomas	120	50	35·18	+0·27	35·45	0·26	4·516 386 9	32 838·77
	Haskin	25	18	44·06	−0·37	43·69	0·25	4·213 594 0	16 352·87
				00·21			0·76		
30	Bébé Mound	52	31	07·50	−0·80	06·70	0·34	4·385 722 8	24 306·52
	Eckman	32	16	05·79	−0·32	05·47	0·34	4·213 593 9	16 352·87
	Thomas	95	12	49·21	−0·37	48·84	0·33	4·484 348 6	30 503·42
				02·50			1·01		

(*d*) *Adjusted triangles, Missouri and Kansas*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
31	Kanwaka	49	20	49·29	+1·12	50·41	0·85	4·484 348 6	30 503·42
	Eckman	71	18	07·35	+0·25	07·60	0·84	4·580 746 8	38 084·37
	Bébé Mound	59	21	03·53	+1·00	04·53	0·85	4·538 948 8	34 589·86
				00·17			2·54		
32	Simmons	39	54	39·40	−0·02	39·38	0·83	4·484 348 6	30 503·42
	Eckman	43	07	59·12	+0·69	59·81	0·83	4·511 951 3	32 505·08
	Bébé Mound	96	57	23·13	+0·18	23·31	0·84	4·673 880 3	47 193·29
				01·65			2·50		
33	Simmons	84	15	60·62	+0·07	60·69	0·64	4·580 746 8	38 084·37
	Kanwaka	58	07	43·20	−0·75	42·45	0·64	4·511 951 4	32 505·09
	Bébé Mound	37	36	19·60	−0·82	18·78	0·64	4·368 407 5	23 356·48
				03·42			1·92		
34	Kanwaka	107	28	32·49	+0·37	32·86	0·66	4·673 880 3	47 193·29
	Eckman	28	10	08·23	−0·44	07·79	0·65	4·368 407 6	23 356·49
	Simmons	44	21	21·22	+0·09	21·31	0·65	4·538 948 8	34 589·86
				01·94			1·96		
35	Elevation	39	49	00·65	+0·24	00·89	0·62	4·368 407 5	23 356·48
	Kanwaka	79	56	07·91	−0·20	07·71	0·61	4·555 265 5	35 914·14
	Simmons	60	14	53·71	−0·46	53·25	0·62	4·500 611 2	31 667·31
				02·27			1·85		
36	Mabon	35	19	40·69	−0·21	40·48	0·60	4·368 407 5	23 356·48
	Kanwaka	49	11	05·88	+0·08	05·96	0·60	4·485 283 5	30 569·16
	Simmons	95	29	15·50	−0·13	15·37	0·61	4·604 294 9	40 206·37
				02·07			1·81		
37	Mabon	86	35	08·78	+0·31	09·09	0·53	4·555 265 5	35 914·14
	Elevation	58	10	30·31	+0·09	30·40	0·54	4·485 283 4	30 569·15
	Simmons	35	14	21·79	+0·33	22·12	0·54	4·317 207 7	20 759·06
				00·88			1·61		
38	Elevation	97	59	30·96	+0·34	31·30	0·55	4·604 294 9	40 206·37
	Kanwaka	30	45	02·03	−0·28	01·75	0·55	4·317 207 6	20 759·06
	Mabon	51	15	28·09	+0·51	28·60	0·55	4·500 611 2	31 667·31
				01·08			1·65		
39	Powell	73	02	53·17	+0·46	53·63	0·24	4·317 207 7	20 759·06
	Elevation	60	04	24·20	+0·34	24·54	0·24	4·274 351 3	18 808·38
	Mabon	46	52	42·69	−0·14	42·55	0·24	4·199 766 2	15 840·40
				00·06			0·72		

(*d*) *Adjusted triangles, Missouri and Kansas*—Continued.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
40	Clark	37	22	54·45	+0·89	55·34	0·52	4·317 207 7	20 759·06
	Elevation	61	38	23·84	+0·31	24·15	0·52	4·478 402 3	30 088·62
	Mabon	80	58	41·94	+0·14	42·08	0·53	4·528 523 4	33 769·40
				00·23			1·57		
41	Clark	35	59	54·75	+1·18	55·93	0·27	4·274 351 3	18 808·38
	Powell	109	54	04·98	+0·37	05·35	0·27	4·478 402 3	30 088·62
	Mabon	34	05	59·25	+0·28	59·53	0·27	4·253 826 2	17 940·16
				58·98			0·81		
42	Powell	177	03	01·85	−0·830	01·020	0·013	4·528 523 4	33 769·40
	Clark	1	22	59·70	−0·295	59·405	0·012	4·199 766 2	15 840·40
	Elevation	1	33	59·64	−0·028	59·612	0·012	4·253 826 1	17 940·15
				01·19			0·037		
43	Adams	87	39	46·87	+0·46	47·33	0·47	4·528 523 4	33 769·40
	Elevation	36	45	05·19	−0·74	04·45	0·48	4·305 832 9	20 222·41
	Clark	55	35	09·45	+0·20	09·65	0·48	4·445 325 2	27 882·08
				01·51			1·43		
44	Adams	32	26	13·91	−0·35	13·56	0·23	4·199 766 2	15 840·40
	Elevation	38	19	04·83	−0·77	04·06	0·23	4·262 706 7	18 310·77
	Powell	109	14	43·75	−0·67	43·08	0·24	4·445 325 3	27 882·09
				02·49			0·70		
45	Adams	55	13	32·96	+0·81	33·77	0·26	4·253 826 2	17 940·16
	Powell	67	48	18·10	−0·16	17·94	0·25	4·305 832 9	20 222·41
	Clark	56	58	09·15	−0·09	09·06	0·26	4·262 706 7	18 310·77
				00·21			0·77		
46	Meyer	56	09	11·57	−0·32	11·25	0·29	4·305 832 9	20 222·41
	Adams	45	18	49·86	−1·07	48·79	0·29	4·238 326 6	17 311·18
	Clark	78	32	01·12	−0·29	00·83	0·29	4·377 722 6	23 862·87
				02·55			0·87		
47	Zean Dale	35	16	23·47	−0·12	23·35	0·50	4·305 832 9	20 222·41
	Adams	87	27	04·54	−0·58	03·96	0·51	4·543 871 1	34 984·13
	Clark	57	16	34·76	−0·56	34·20	0·50	4·469 244 1	29 460·77
				02·77			1·51		
48	Zean Dale	53	41	17·47	+0·01	17·48	0·40	4·377 722 6	23 862·87
	Adams	42	08	14·68	+0·49	15·17	0·40	4·298 157 7	19 868·16
	Meyer	84	10	28·35	+0·20	28·55	0·40	4·469 243 9	29 460·76
				00·50			1·20		

(*d*) *Adjusted triangles, Missouri and Kansas*—Continued.

No.	Station.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
49	Meyer	140	19	39·92	−0·12	39·80	0·18	4·543 871 1	34 984·13
	Zean Dale	18	24	54·00	+0·13	54·13	0·19	4·238 326 5	17 311·17
	Clark	21	15	26·36	+0·27	26·63	0·19	4·298 157 7	19 868·16
				00·28			0·56		
50	Reinhard	44	44	26·05	−0·03	26·02	0·39	4·298 157 7	19 868·16
	Zean Dale	56	23	09·15	+0·41	09·56	0·39	4·371 181 8	23 506·17
	Meyer	78	52	25·43	+0·15	25·58	0·38	4·442 408 3	27 695·44
				00·63			1·16		
51	Reinhard	61	14	50·98	+1·01	51·99	0·79	4·543 871 1	34 984·13
	Zean Dale	74	48	03·15	+0·54	03·69	0·79	4·585 553 4	38 508·21
	Clark	43	57	06·75	−0·06	06·69	0·79	4·442 408 4	27 695·45
				00·88			2·37		
52	Meyer	140	47	54·65	−0·03	54·62	0·21	4·585 553 4	38 508·21
	Clark	22	41	40·39	−0·33	40·06	0·22	4·371 181 9	23 506·17
	Reinhard	16	30	24·93	+1·04	25·97	0·22	4·238 326 6	17 311·18
				59·97			0·65		
53	Humboldt	90	25	32·39	−0·33	32·06	0·32	4·442 408 4	27 695·45
	Zean Dale	41	02	33·19	−0·66	32·53	0·32	4·259 731 6	18 185·77
	Reinhard	48	31	56·35	+0·02	56·37	0·32	4·317 092 5	20 753·56
				01·93			0·96		
54	Erricssen	46	36	50·96	+1·25	52·21	0·67	4·442 408 4	27 695·45
	Zean Dale	84	47	38·04	+0·19	38·23	0·66	4·579 230 1	37 951·60
	Reinhard	48	35	32·62	−1·06	31·56	0·67	4·456 097 0	28 582·29
				01·62			2·00		
55	Erricssen	46	33	33·38	+0·84	34·22	0·35	4·317 092 5	20 753·56
	Zean Dale	43	45	04·85	+0·84	05·69	0·35	4·295 915 5	19 765·85
	Humboldt	89	41	20·42	+0·71	21·13	0·34	4·456 097 0	28 582·29
				58·65			1·04		
56	Humboldt	179	53	07·19	−0·384 4	06·805 6	0·000 6	4·579 230 1	37 951·60
	Reinhard	0	03	36·27	−1·070 4	35·199 6	0·000 6	4·295 915 6	19 765·85
	Erricssen	0	03	17·58	+0·416 6	17·996 6	0·000 6	4·259 731 7	18 185·77
				01·04			0·001 8		
57	Robbins	53	59	07·73	+0·58	08·31	0·25	4·295 915 5	19 765·85
	Erricssen	37	36	47·31	−0·06	47·25	0·25	4·173 599 0	14 914·17
	Humboldt	88	24	05·34	−0·15	05·19	0·25	4·387 868 3	24 426·90
				00·38			0·75		

(*d*) *Adjusted triangles, Missouri and Kansas*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
58	Robbins	49	45	34·82	−0·39	34·43	0·23	4·259 731 6	18 185·77
	Humboldt	91	29	01·85	−0·23	01·62	0·23	4·376 868 1	23 815·96
	Reinhard	38	45	24·81	−0·17	24·64	0·23	4·173 599 1	14 914·17
				01·48			0·69		
59	Robbins	103	44	42·55	+0·19	42·74	0·47	4·579 230 1	37 951·60
	Erricssen	37	33	29·73	−0·48	29·25	0·48	4·376 868 2	23 815·97
	Reinhard	38	41	48·54	+0·90	49·44	0·48	4·387 868 4	24 426·90
				00·82			1·43		
60	White City	79	47	11·37	+1·11	12·48	0·27	4·376 868 1	23 815·96
	Robbins	41	31	00·82	+0·39	01·21	0·28	4·205 214 2	16 040·36
	Reinhard	58	41	46·84	+0·30	47·14	0·28	4·315 479 0	20 676·60
				59·03			0·83		
61	Wilmer	51	58	36·95	−0·36	36·59	0·51	4·387 868 3	24 426·90
	Erricssen	57	00	39·96	+0·26	40·22	0·51	4·415 120 0	26 008·78
	Robbins	71	00	45·25	−0·53	44·72	0·51	4·467 176 4	29 320·84
				02·16			1·53		
62	Taylor	51	13	33·12	+0·87	33·99	0·36	4·315 479 0	20 676·60
	Robbins	75	56	33·88	−0·13	33·75	0·36	4·410 390 2	25 727·07
	White City	52	49	53·59	−0·25	53·34	0·36	4·324 977 4	21 133·79
				00·59			1·08		
63	Taylor	64	51	36·99	−0·04	36·95	0·43	4·415 120 0	26 008·78
	Wilmer	47	21	26·03	+0·73	26·76	0·43	4·324 977 6	21 133·80
	Robbins	67	46	57·50	+0·08	57·58	0·43	4·424 836 4	26 597·23
				00·52			1·29		
64	Frey	90	23	36·44	+0·42	36·86	0·29	4·424 836 4	26 597·23
	Wilmer	53	08	06·03	+0·42	06·45	0·28	4·327 964 7	21 279·66
	Taylor	36	28	17·72	−0·18	17·54	0·28	4·198 941 7	15 810·36
				00·19			0·85		
65	Vine Creek	40	20	07·10	+0·62	07·72	0·68	4·424 836 4	26 597·23
	Wilmer	92	02	32·31	−0·27	32·04	0·69	4·613 482 1	41 065·97
	Taylor	47	37	22·89	−0·60	22·29	0·68	4·482 239 1	30 355·62
				02·30			2·05		
66	Frey	112	16	48·48	−0·64	47·84	0·25	4·482 239 1	30 355·62
	Vine Creek	28	48	47·01	+0·33	47·34	0·26	4·198 941 7	15 810·36
	Wilmer	38	54	26·28	−0·69	25·59	0·26	4·313 936 6	20 603·29
				01·77			0·77		

(d) Adjusted triangles, Missouri and Kansas—Completed.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
67	Frey	157	19	35·08	+0·22	35·30	0·15	4·613 482 1	41 065·97
	Taylor	11	09	05·17	−0·42	04·75	0·14	4·313 936 6	20 603·29
	Vine Creek	11	31	20·09	+0·29	20·38	0·14	4·327 964 7	21 279·66
				00·34			0·43		
68	Iron Mound	61	10	06·64	+0·61	07·25	1·13	4·613 482 1	41 065·97
	Vine Creek	71	53	08·67	−0·05	08·62	1·13	4·648 881 1	44 553·42
	Taylor	46	56	46·42	+1·10	47·52	1·13	4·534 704 9	34 253·50
				01·73			3·39		
69	Frey	93	25	41·16	−0·05	41·11	0·68	4·648 881 1	44 553·42
	Taylor	58	05	51·59	+0·68	52·27	0·68	4·578 541 1	37 891·44
	Iron Mound	28	28	28·60	+0·06	28·66	0·68	4·327 964 8	21 279·67
				01·35			2·04		
70	Vine Creek	83	24	28·76	+0·24	29·00	0·60	4·578 541 1	37 891·44
	Frey	63	53	53·92	+0·27	54·19	0·59	4·534 705 0	34 253·50
	Iron Mound	32	41	38·04	+0·55	38·59	0·59	4·313 936 7	20 603·30
				00·72			1·78		

(e) Precision of the Missouri-Kansas series of triangles.

For the purpose of determining the uncertainty of the developed length of the triangulation, the series may be divided into three parts by the lines Normal-Caldwell and Zean Dale-Reinhard. The probable error in length (in parts of the length) of each section may with sufficient accuracy be taken as the mean of the probable errors of the limiting lines. The probable error in length, due to the angular measures, of any side may be computed by the usual formulæ—

$$m=\sqrt{\frac{2[vv]}{c}},\quad u_{a_n}=\tfrac{2}{3}\left(\delta_{a_n}\right)^{-2}\Sigma_{a_1}^{a_n}\left[\delta_A^2+\delta_A\delta_B+\delta_B^2\right] \text{ and } e_{a_n}=0\text{·}674\,5\; m\sqrt{u_{a_n}}$$

From the figure adjustment involving 77 equations and 188 directions we have $m=\pm 0''\text{·}73$. For the line Normal to Caldwell $\delta_{a_n}=20\text{·}4$ in units of the sixth place of decimals in the logarithm.

Starting from the side Hubbard to Hughes of the Versailles Base Net $\Sigma=54\text{·}8$ (7 triangles), $e_{a_n}=\pm 0\text{·}147$ metre, $e_b=\pm 0\text{·}062$ metre, and $e_1=\pm 0\text{·}160$ metre. Starting from the side Vine Creek to Iron Mound of the Salina Base Net $\Sigma=164\text{·}3$ (25 triangles), $e_{a_n}=\pm 0\text{·}254$ metre, $e_b=\pm 0\text{·}081$ metre, and $e_2=\pm 0\text{·}267$ metre. Then for the probable error of the length of Normal to Caldwell as a side of the adjusted triangulation $e=\frac{e_1 e_2}{\sqrt{e_1^2+e_2^2}}=\pm 0\text{·}137$ metre, or about $\frac{1}{188\,000}$ part of the length. For the side Zean Dale to Reinhard $\delta_{a_n}=15\text{·}7$. Starting from the side Hub-

bard to Hughes $\Sigma = 185.7$ (26 triangles), $e_{a_n} = \pm 0.351$ metre, $e_b = \pm 0.080$ metre, and $e_1 = \pm 0.360$ metre. Starting from the side Vine Creek to Iron Mound $\Sigma = 33.4$ (6 triangles), $e_{a_n} = \pm 0.149$ metre, $e_b = \pm 0.105$ metre, and $e_2 = \pm 0.182$ metre. Finally $e = \pm 0.162$ metre, or about $\frac{1}{171\,000}$ part of the length.

For the effect on the arc we have approximately (the distances being measured along the thirty-ninth parallel between the projections of the middle points of the terminal lines)—

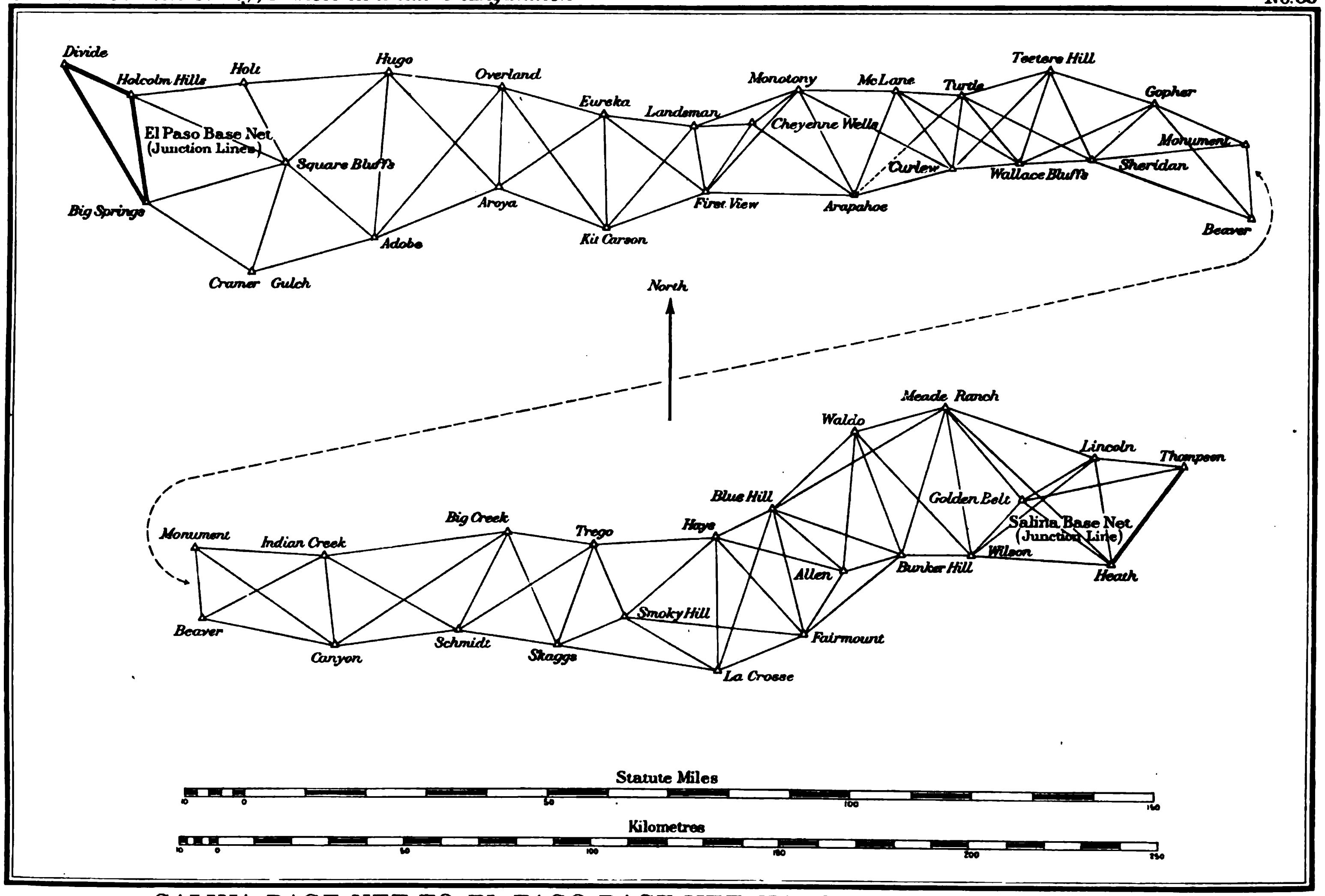
Terminal lines.	Distance.	Probable errors.		Average.	
	Km.				*m.*
Hubbard and Hughes to Normal and Caldwell	73.6	$\frac{1}{344\,000}$	$\frac{1}{155\,000}$	$\frac{1}{214\,000}$	±0.34
Normal and Caldwell to Zean Dale and Reinhard	237.4	$\frac{1}{155\,000}$	$\frac{1}{171\,000}$	$\frac{1}{163\,000}$	1.46
Zean Dale and Reinhard to Vine Creek and Iron Mound	83.5	$\frac{1}{171\,000}$	$\frac{1}{263\,500}$	$\frac{1}{207\,000}$	0.40
	394.5			Sum	±2.20

8. THE KANSAS-COLORADO SERIES OF TRIANGLES, 1880–81, 1891–92–93, 1895.

(*a*) *Introduction.*

Between the Salina Base in central Kansas and the El Paso Base in Colorado on the eastern flank of the Rocky Mountains the connecting triangulation follows the trend of the Smoky Hill River to the eastern Colorado boundary line, and along the whole line deviates but little from the course of the Union Pacific Railroad. The ascent of the Smoky Hill Valley is gradual up to First View, which is at an altitude of nearly 4 600 feet; farther to the west the ridge forming the watershed between the Arkansas River and the South Platte River rises to 6 000 feet and more, the El Paso Base itself lying at an altitude of not quite 6 800 feet. In western Kansas the land is barely undulating, but in the Colorado region it becomes slightly rolling; the streams are generally cut deeply into the sloping treeless plains. In order to cross the ridge at First View, it was found necessary to mount the instrument about 35 feet above ground, but elsewhere observations were generally made at the ordinary height of the eye. Measured along the axis of the triangulation the distance from base net to base net is 564 kilometres or 350½ statute miles.

Coast and Geodetic Survey, Transcontinental Triangulation. No. 33



SALINA BASE NET TO EL PASO BASE NET. KANSAS-COLORADO SERIES

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895.*

Heath, Ellsworth County, Kansas. July 8 to July 25, 1891. 35-centimetre theodolite, No. 10. Telescope above ground 17·30 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
6	Lincoln	0	00	00·00	−0·01	59·99	....	+0·19	00·18
	Thompson	46	04	27·51	+0·03	27·54	+0·68	....	28·22
	Vine Creek	72	07	24·06	+0·02	24·08	−1·11	....	22·97
	North Pole Mound	81	17	05·14	+0·02	05·16	−0·35	....	04·81
	Iron Mound	103	36	35·87	−0·01	35·86	+0·77	....	36·63
	Ellsworth water tower pole	241	44	04·27	+0·03	04·30	....	....	
3	Wilson	282	15	47·25	0·00	47·25	....	−0·35	46·90
4	Golden Belt	312	37	28·69	−0·03	28·66	....	−1·07	27·59
5	Meades Ranch	323	40	31·61	−0·04	31·57	....	+0·72	32·29

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·84.

Thompson, Ottawa County, Kansas. August 6 to August 10, 1891. 35-centimetre theodolite, No. 10. Telescope above ground 1·68 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Heath	0	00	00·00	+0·04	00·04	−0·21	....	59·83
1	Golden Belt	38	54	02·24	+0·02	02·26	....	+0·64	02·90
2	Lincoln	58	20	08·93	−0·01	08·92	....	+0·30	09·22
	Vine Creek	227	20	01·45	+0·01	01·46	+0·60	....	02·06
	North Pole Mound	267	03	34·82	−0·03	34·79	−0·86	....	33·93
	Iron Mound	279	10	48·50	−0·03	48·47	+0·46	....	48·93

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·56.

Lincoln, Lincoln County, Kansas. August 22 to August 31, 1891. 35-centimetre theodolite, No. 10. Telescope above ground 6·07 metre. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
8	Heath	0	00	00·00	−0·01	59·99	+0·13	00·12
9	Wilson	62	10	33·15	+0·04	33·19	+1·08	34·27
10	Golden Belt	64	07	02·20	+0·03	02·23	−0·64	01·59
11	Meades Ranch	120	03	48·52	−0·03	48·49	+0·17	48·66
7	Thompson	284	24	36·70	−0·01	36·69	−0·74	35·95

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·61.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895*—Continued.

Golden Belt, Lincoln County, Kansas. September 12 to September 23, 1891. 35-centimetre theodolite, No. 10. Telescope above ground 1·77 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
12	Lincoln	0	00	00·00	+0·03	00·03	−0·45	59·58
13	Thompson	20	51	27·80	+0·02	27·82	+0·64	28·46
14	Heath	68	30	27·07	-0·03	27·04	−0·13	26·91
15	Wilson	175	56	58·10	+0·04	58·14	−0·04	58·10
16	Meades Ranch	268	15	18·95	−0·04	18·91	−0·02	18·89

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·49.

Meades Ranch, Osborne County, Kansas. September 29 to October 16, 1891. 35-centimetre theodolite, No. 10. Telescope above ground 1·62 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
26	Wilson	0	00	00·00	−0·01	59·99	−0·08	59·91
27	Bunker Hill	26	40	18·63	+0·02	18·65	+0·25	18·90
28	Blue Hill	67	49	15·82	+0·04	15·86	+0·22	16·08
29	Waldo	82	10	52·84	+0·02	52·86	−0·24	52·62
23	Lincoln	297	36	28·74	−0·02	28·72	−0·19	28·53
24	Heath	321	13	13·46	−0·04	13·42	+1·17	14·59
25	Golden Belt	329	55	03·82	−0·03	03·79	−1·13	02·66

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·72.

Wilson, Russell County, Kansas. October 24 to November 9, 1891. 35-centimetre theodolite, No. 10. Telescope above ground 15·10 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
20	Golden Belt	0	00	00·00	+0·03	00·03	−0·70	59·33
21	Lincoln	2	06	33·33	+0·03	33·36	+0·21	33·57
22	Heath	42	11	48·31	0·00	48·31	+0·45	48·76
	Ellsworth water tower	71	34	59·67	....	....	....	....
17	Bunker Hill	221	30	50·47	0·00	50·47	+0·34	50·81
18	Waldo	267	34	02·89	−0·04	02·85	−0·16	02·69
19	Meades Ranch	302	23	15·79	−0·01	15·78	−0·14	15·64

Probable error of a single observation of a direction (*D.* and *R.*) = 0″·76.

Bunker Hill, Russell County, Kansas. May 26 to June 16, 1892. 35-centimetre theodolite, No. 10. Telescope above ground 12·09 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
	Russell Southeast	0	00	00·00	....	....	....	00·00
	Russell Northwest	27	03	41·08	....	....	....	....
32	Blue Hill	33	32	12·99	−0·03	12·96	+0·63	13·59
33	Waldo	85	13	35·25	−0·02	35·23	−0·32	34·91
34	Meades Ranch	123	22	08·71	+0·02	08·73	+0·21	08·94
35	Wilson	195	49	27·58	0·00	27·58	−0·54	27·04
30	Fairmount	333	37	51·96	+0·04	52·00	+1·38	53·38
31	Allen	354	36	02·45	+0·02	02·47	−1·36	01·11

Probable error of a single observation of a direction (*D.* and *R.*) = + 0″·85.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895*—Continued.

Waldo, Osborne County, Kansas. June 23 to July 7, 1892. 35-centimetre theodolite, No. 10. Telescope above ground 1·72 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Russell Southeast	0	00	00·00	....	....	....	00·00
	Russell Northwest	5	31	38·18	....	....	....	....
39	Allen	11	56	08·60	+0·01	08·61	−1·37	07·24
40	Blue Hill	55	28	07·66	+0·04	07·70	+0·33	08·03
36	Meades Ranch	261	46	52·66	+0·02	52·68	+0·08	52·76
37	Wilson	324	46	48·94	−0·04	48·90	+0·81	49·71
38	Bunker Hill	348	07	47·14	−0·02	47·12	+0·14	47·26

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·70.

Allen, Russell County, Kansas. July 13 to July 25, 1892. 35-centimetre theodolite, No. 10. Telescope above ground 7·28 metres. F. D. Granger, observer.

		°	′	″	″	″	″	″
	Russell Northwest	0	00	00·00	....	....	....	00·00
	Russell Southeast	37	28	57·42	....	....	....	....
45	Bunker Hill	42	11	16·19	+0·02	16·21	−0·03	16·18
41	Fairmount	185	41	56·09	+0·04	56·13	−0·95	55·18
42	Hays	257	02	04·46	−0·02	04·44	+0·17	04·61
43	Blue Hill	282	32	08·62	−0·04	08·58	−0·14	08·44
44	Waldo	336	37	07·66	+0·01	07·67	+0·96	08·63

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·69.

Fairmount, Barton County, Kansas. August 1 to August 15, 1892. 35-centimetre theodolite, No. 10. Telescope above ground 5·92 metres. F. D. Granger, observer.

		°	′	″	″	″	″	″
57	Allen	0	00	00·00	+0·04	00·04	−0·93	$\overline{59}$·11
58	Bunker Hill	15	31	11·80	+0·04	11·84	+1·01	12·85
53	La Crosse	214	19	34·44	+0·03	34·47	−0·55	33·92
54	Smoky Hill	242	37	55·44	−0·01	55·43	+0·90	56·33
55	Hays	284	34	52·31	−0·04	52·27	−0·40	51·87
56	Blue Hill	312	03	35·94	−0·02	35·92	−0·02	35·90

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·79.

La Crosse, Rush County, Kansas. August 24 to September 1, 1892. 35-centimetre theodolite, No. 10 Telescope above ground 7·46 metres. F. D. Granger, observer.

		°	′	″	″	″	″	″
67	Hays	0	00	00·00	0·00	00·00	+0·21	00·21
68	Blue Hill	19	06	24·71	+0·03	24·74	+1·16	25·90
69	Fairmount	68	50	05·00	+0·03	05·03	−0·56	04·47
65	Skaggs	279	57	29·32	−0·02	29·30	−0·01	29·29
66	Smoky Hill	301	34	38·90	−0·04	38·86	−0·80	38·06

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·61.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895*—Continued.

Hays, Ellis County, Kansas. September 9 to September 26, 1892. 35-centimetre theodolite, No. 10. Telescope above ground 7·32 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
62	La Crosse	0	00	00·00	0·00	00·00	−0·68	59·32
63	Smoky Hill	49	23	59·00	+0·05	59·05	−0·28	58·77
64	Trego	87	15	03·12	+0·01	03·13	+0·44	03·57
59	Blue Hill	243	16	47·55	+0·03	47·58	−0·56	47·02
60	Allen	285	50	34·20	−0·02	34·18	+0·16	34·34
61	Fairmount	319	05	18·56	−0·04	18·52	+0·92	19·44

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·90.

Smoky Hill, Ellis County, Kansas. July 31 to August 8, 1893. 35-centimetre theodolite, No. 10. Telescope above ground 1·64 metres. F. D. Granger, observer.

		°	′	″	″	″	″	″
71	Trego	0	00	00·00	−0·03	59·97	+0·05	00·02
72	Hays	71	03	01·43	+0·04	01·47	−0·43	01·04
73	Fairmount	118	47	28·26	−0·01	28·25	+0·75	29·00
74	La Crosse	143	13	41·91	−0·04	41·87	−0·25	41·62
70	Skaggs	269	07	17·08	+0·04	17·12	−0·12	17·00

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·58.

Blue Hill, Ellis County, Kansas. October 6 to October 26, 1892. 35-centimetre theodolite, No. 10. Telescope above ground 4·42 metres. F. D. Granger, observer.

		°	′	″	″	″	″	″
49	Allen	0	00	00·00	−0·04	59·96	−1·37	58·59
50	Fairmount	35	13	23·49	−0·02	23·47	0·00	23·47
51	La Crosse	67	45	43·95	+0·03	43·98	+1·14	45·12
52	Hays	111	56	08·38	+0·04	08·42	+0·05	08·47
46	Waldo	277	36	57·68	+0·04	57·72	−0·19	57·53
47	Meades Ranch	289	34	06·62	+0·03	06·65	−0·03	06·62
48	Bunker Hill	338	35	17·55	−0·02	17·53	+0·40	17·93
	Russell Northwest	341	15	05·98	....	....	....	....
	Russell Southeast	345	58	52·24	....	....	....	....

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·82.

Trego, Trego County, Kansas. August 15 to August 25, 1893. 35-centimetre theodolite, No. 10. Telescope above ground 12·19 metres. H. L. Stidham, observer.

		°	′	″	″	″	″	″
77	Skaggs	0	00	00·00	+0·03	00·03	+0·12	00·15
78	Schmidt	37	33	32·53	+0·05	32·58	+0·21	32·79
79	Bay Creek	77	09	51·64	−0·01	51·63	+0·03	51·66
75	Hays	246	00	30·71	0·00	30·71	−0·19	30·52
76	Smoky Hill	317	06	26·48	−0·03	26·45	−0·17	26·28

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·68.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895*—Continued.

Big Creek, Trego County, Kansas. May 24 to June 13, 1893. 35-centimetre theodolite, No. 10. Telescope above ground 14·94 metres. F. D. Granger and H. L. Stidham, observers.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
87	Schmidt	0	00	00·00	+0·04	00·04	−0·03	00·01
88	Canyon	30	23	31·46	+0·05	31·51	+0·54	32·05
89	Indian Creek	55	44	14·38	+0·01	14·39	−0·51	13·88
85	Trego	251	01	45·42	−0·01	45·41	+0·26	45·67
86	Skaggs	309	25	42·34	−0·04	42·30	−0·26	42·04

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·65.

Schmidt, Ness County, Kansas. June 24 to July 9, 1893. 35-centimetre theodolite, No. 10. Telescope above ground 16·99 metres. F. D. Granger and H. L. Stidham, observers.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level ″	Resulting seconds ″	Corrections ″	Final seconds ″
92	Big Creek	0	00	00·00	+0·04	00·04	+0·12	00·16
93	Trego	31	25	29·35	+0·04	29·39	−0·83	28·56
94	Skaggs	72	32	40·98	−0·02	40·96	+0·51	41·47
90	Canyon	236	02	58·50	+0·01	58·51	+0·13	58·64
91	Indian Creek	270	56	03·15	−0·05	03·10	+0·07	03·17

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·80.

Skaggs, Ness County, Kansas. July 14 to July 25, 1893. 35-centimetre theodolite, No. 10. Telescope above ground 15·18 metres. F. D. Granger, observer.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level ″	Resulting seconds ″	Corrections ″	Final seconds ″
82	Trego	0	00	00·00	+0·03	00·03	+0·35	00·38
83	Smoky Hill	46	13	44·62	+0·03	44·65	−0·13	44·52
84	La Crosse	78	43	01·24	−0·01	01·23	+0·27	01·50
80	Schmidt	258	40	44·46	−0·02	44·44	−0·39	44·05
81	Big Creek	315	33	46·76	−0·04	46·72	−0·10	46·62

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·58.

Indian Creek, Grove County, Kansas. September 11 to September 30, 1891. 25-centimetre theodolite, No. 74. Telescope above ground . . . . W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level ″	Resulting seconds ″	Corrections ″	Final seconds ″
95	Big Creek	0	00	00·00	+0·01	00·01	+0·36	00·37
	Bluff	9	59	57·86	....	....	....	....
	Castle Rock	10	22	29·42	....	....	...	...
96	Schmidt	35	11	52·26	−0·04	52·22	+0·28	52·50
97	Canyon	89	46	12·71	−0·02	12·69	−0·42	12·27
	Hill	101	31	43·13	....	....	....	....
98	Beaver	162	39	47·57	+0·05	47·62	−0·04	47·58
99	Monument	193	42	19·64	−0·01	19·63	−0·18	19·45

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·96.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895*—Continued.

Canyon, Lane County, Kansas. September 1 to October 7, 1891. 30-centimetre theodolite, No. 16. Telescope above ground 10·23 metres. F. W. Perkins, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
100	Beaver	0	00	00·00	−0·03	59·97	+0·33	00·30
	Hill	5	14	49·52	....	....	....	....
101	Monument	23	22	39·07	−0·06	39·01	−0·16	38·85
102	Indian Creek	70	29	29·00	−0·02	28·98	+0·36	29·34
	Bluff	121	03	02·33	....	....	....	....
	Castle Rock	125	04	35·64	....	....	....	....
103	Big Creek	135	22	38·46	+0·05	38·51	+0·08	38·59
104	Schmidt	161	02	07·66	+0·01	07·67	−0·61	07·06

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·15.

Beaver, Logan County, Kansas. July 28 to October 25, 1891. 30-centimetre theodolite, No. 16. Telescope above ground . . . . F. W. Perkins, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
105	Sheridan	0	00	00·00	−0·04	59·96	+0·64	00·60
106	Gopher	29	42	10·03	−0·07	09·96	−0·17	09·79
107	Monument	64	52	35·91	−0·01	35·90	+0·01	35·91
108	Indian Creek	134	55	06·89	−0·04	06·93	−0·05	06·88
	Hill	170	44	55·64	....	....	....	....
109	Canyon	171	32	05·10	−0·02	05·08	−0·42	04·66

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·92.

Monument, Logan County, Kansas. August 10 to September 4, 1891. 25-centimetre theodolite, No. 74. Telescope above ground . . . . W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
110	Indian Creek	0	00	00·00	−0·01	59·99	+0·41	00·40
111	Canyon	28	57	04·79	−0·05	04·74	+0·06	04·80
	Hill	31	00	53·30	....	....	....	....
112	Beaver	78	54	59·15	−0·01	59·14	+0·15	59·29
113	Sheridan	168	26	02·18	+0·01	02·19	−0·64	01·55
114	Gopher	197	50	13·40	−0·05	13·35	+0·01	13·36

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·90.

Gopher, Logan County, Kansas. July 31 to August 8, 1891. 25-centimetre theodolite, No. 74. Telescope above ground . . . . W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
115	Monument	0	00	00·00	−0·05	59·95	+0·42	00·37
116	Beaver	25	54	21·62	−0·06	21·56	−0·26	21·30
117	Sheridan	116	13	09·27	+0·07	09·34	+0·08	09·42
118	Wallace Bluffs	133	44	23·23	+0·05	23·28	−0·53	22·75
119	Teeters Hill	175	11	54·36	−0·04	54·32	+0·28	54·60

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·76.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895*—Continued.

Sheridan, Logan County, Kansas. July 8 to November 17, 1891. 30-centimetre theodolite, No. 16. Telescope above ground . . . . F. W. Perkins, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
120	Wallace Bluffs	0	00	00·00	+0·01	00·01	−0·05	59·96
	Pond	26	05	18·55	....	....	....	....
121	Turtle	30	40	59·77	−0·06	59·71	+0·45	60·16
122	Teeters Hill	69	16	58·38	−0·05	58·33	−0·35	57·98
123	Gopher	142	33	02·68	+0·07	02·75	+0·29	03·04
124	Monument	176	55	43·26	+0·01	43·27	+0·23	43·50
125	Beaver	202	32	08·56	−0·04	08·52	−0·56	07·96

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·90.

Teeters Hill, Logan County, Kansas. July 20 to July 27, 1891. 25-centimetre theodolite, No. 74. Telescope above ground . . . . W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level ″	Resulting seconds ″	Corrections ″	Final seconds ″
126	Gopher	0	00	00·00	0·04	59·96	+0·01	59·97
127	Sheridan	47	45	11·46	−0·05	11·41	−0·26	11·15
128	Wallace Bluffs	92	05	47·95	+0·05	48·00	+0·43	48·43
129	Curlew	117	38	56·61	+0·08	56·69	+0·44	57·13
	Pond	136	39	08·80	....	....	....	....
130	Turtle	148	38	40·76	+0·03	40·79	−0·62	40·17

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·51.

Wallace Bluffs, Wallace County, Kansas. June 15 to November 26, 1891. 30-centimetre theodolite, No. 16. Telescope above ground . . . . F. W. Perkins and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level ″	Resulting seconds ″	Corrections ″	Final seconds ″
131	Curlew	0	00	00·00	+0·01	00·01	−0·06	59·95
132	McLane	34	41	37·92	−0·07	37·85	−0·14	37·71
	Pond	52	35	19·03	....	....	....	....
133	Turtle	54	46	46·96	−0·07	46·89	−0·33	47·22
134	Teeters Hill	113	15	27·89	+0·04	27·93	+0·06	27·99
135	Gopher	159	42	09·64	+0·05	09·69	−0·06	09·63
136	Sheridan	179	37	54·03	+0·01	54·04	−0·14	53·90

Probable error of a single observation of a direction (*D.* and *R.*) = ±1″·05.

Turtle, Wallace County, Kansas. October 10 to November 7, 1891. 25-centimetre theodolite, No. 74. Telescope above ground . . . . W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level ″	Resulting seconds ″	Corrections ″	Final seconds ″
137	Teeters Hill	0	00	00·00	+0·03	00·03	+0·37	00·40
138	Sheridan	40	30	34·65	−0·06	34·59	+0·58	35·17
139	Wallace Bluffs	64	58	29·68	−0·07	29·61	−0·32	29·29
	Pond	73	07	17·76	....	....	....	....
140	Curlew	109	33	02·74	+0·02	02·76	−0·18	02·58
141	Arapahoe	149	31	17·15	+0·08	17·23	0·42	16·81
142	McLane	196	59	12·51	−0·01	12·50	−0·03	12·47

Probable error of a single observation of a direction (*D.* and *R.*) = ±1″·12.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895*—Continued.

Curlew, Wallace County, Kansas. November 28 to December 12, 1891, and July 23 to July 28, 1892. 30-centimetre theodolite, No. 16. Telescope above ground 6·57 metres. F. W. Perkins, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
143	Arapahoe	0	00	00·00	+0·04	00·04	−0·40	59·64
144	Monotony	44	03	57·56	−0·07	57·49	−0·39	57·88
145	McLane	70	07	54·29	−0·07	54·22	+0·14	54·36
146	Turtle	112	48	34·08	+0·02	34·10	+0·05	34·15
	Pond	123	43	00·25	....	....	....	....
147	Teeters Hill	152	15	50·34	+0·07	50·41	−0·27	50·14
148	Wallace Bluffs	193	27	14·38	+0·01	14·39	+0·09	14·48

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·15.

McLane, Wallace County, Kansas. July 30 to August 12, 1892. 30-centimetre theodolite, No. 16. Telescope above ground . . . . F. W. Perkins, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
149	Turtle	0	00	00·00	−0·01	59·99	+0·42	00·41
	Pond	11	43	20·96	....	....	....	....
150	Wallace Bluffs	27	54	09·33	−0·06	09·27	−0·72	08·55
151	Curlew	49	53	11·69	−0·07	11·62	+0·03	11·65
152	Arapahoe	107	46	24·92	+0·05	24·97	−0·13	24·84
153	Monotony	175	52	09·06	0·00	09·06	+0·40	09·46

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·62.

Arapahoe, Cheyenne County, Colorado. November 24 to November 26, 1891. 25-centimetre theodolite, No. 74. Telescope above ground 12·68 metres. R. E. Duvall, observer. August 13 to September 1, 1892. 30-centimetre theodolite, No. 16. Telescope above ground 12·68 metres. F. W. Perkins and W. B. Fairfield, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
154	First View	0	00	00·00	−0·02	59·98	−0·27	59·71
155	Cheyenne Wells	33	03	37·92	−0·09	37·83	−0·34	37·49
156	Monotony	60	41	14·93	−0·06	14·87	−0·17	14·70
157	McLane	106	32	45·97	+0·05	46·02	+0·31	46·33
	Turtle	..	..	....	....	....	....	....
158	Curlew	158	31	39·70	+0·04	39·74	+0·47	40·21

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·74.

Monotony, Cheyenne County, Colorado. December 1, 1891, and August 22 to September 20, 1892. 25-centimetre theodolite, No. 74. Telescope above ground 12·68 metres. R. E. Duvall, observer in 1891; W. B. Fairfield, observer in 1892.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
159	McLane	0	00	00·00	0·00	00·00	−0·29	59·71
160	Curlew	27	57	07·31	−0·06	07·25	−0·49	06·76
161	Arapahoe	66	02	45·30	−0·06	45·24	+0·05	45·29
162	First View	135	50	58·01	+0·09	58·10	+0·84	58·94
163	Cheyenne Wells	147	15	48·57	+0·08	48·65	−0·42	48·23
164	Landsman	163	46	19·18	+0·05	19·23	+0·31	19·54

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·76.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895*—Continued.

Cheyenne Wells, Cheyenne County, Colorado. October 19 to October 31, 1892. 25-centimetre theodolite, No. 74. Telescope above ground . . . . W. B. Fairfield, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
165	Monotony	0	00	00·00	+0·08	00·08	+0·13	00·21
166	Arapahoe	71	09	20·77	−0·08	20·69	+0·63	21·32
167	First View	160	18	22·28	+0·09	22·37	+0·10	22·47
168	Landsman	212	27	29·72	0·00	29·72	−0·85	28·87

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·77.

First View, Cheyenne County, Colorado. October 18 to November 20, 1892. 30-centimetre theodolite, No. 16. Telescope above ground 9·62 metres. F. W. Perkins, observer.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level ″	Resulting seconds ″	Corrections from figure adjustment ″	Final seconds ″
169	Kit Carson	0	00	00·00	+0·06	00·06	−0·09	$\overline{59}$·97
170	Eureka	57	33	37·48	−0·09	37·39	+0·08	37·47
171	Landsman	99	35	36·24	−0·04	36·20	+0·67	36·87
172	Cheyenne Wells	147	25	30·37	+0·09	30·46	−0·51	29·95
173	Monotony	155	42	18·71	+0·08	18·79	−0·11	18·68
174	Arapahoe	205	12	52·90	−0·01	52·89	−0·04	52·85

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·49.

Landsman, Cheyenne County, Colorado. October 6 to October 15, 1892. 25-centimetre theodolite, No. 74. Telescope above ground . . . . W. B. Fairfield, observer.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level ″	Resulting seconds ″	Corrections from figure adjustment ″	Final seconds ″
175	Monotony	0	00	00·00	+0·05	00·05	−0·24	59·81
176	Cheyenne Wells	15	56	56·61	0·00	56·61	+0·90	57·51
177	First View	95	57	59·28	−0·04	59·24	−0·50	58·74
178	Kit Carson	148	12	39·90	+0·09	39·99	−0·25	39·74
179	Eureka	205	13	38·89	−0·03	38·86	+0·09	38·95

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·71.

Kit Carson, Cheyenne County, Colorado. October 24 to October 30, 1881. 30-centimetre theodolite, No. 108. Telescope above ground 2·11 metres. O. H. Tittmann, observer.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level ″	Resulting seconds ″	Corrections from figure adjustment ″	Final seconds ″
180	Aroya	0	00	00·00	−0·07	$\overline{59}$·93	−0·60	$\overline{59}$·33
181	Overland	32	24	48·58	−0·10	48·48	+0·60	49·08
182	Eureka	67	39	53·21	0·00	53·21	−0·10	53·11
183	Landsman	108	58	51·03	+0·09	51·12	−0·08	51·04
184	First View	137	08	34·15	+0·06	34·21	+0·18	34·39

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·90.

(b) Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895—Continued.

Eureka, Elbert County, Colorado. October 8 to October 17, 1881. 30-centimetre theodolite, No. 108. Telescope above ground 1·90 metres. O. H. Tittmann, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
185	Landsman	0	00	00·00	−0·03	59·97	+0·24	00·21
186	First View	28	42	22·21	−0·09	22·12	−0·52	21·60
187	Kit Carson	81	40	04·71	0·00	04·71	+0·22	04·93
188	Aroya	137	13	18·43	+0·09	18·52	+0·24	18·76
189	Overland	186	32	02·22	−0·05	02·17	−0·17	02·00

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·13.

Aroya, Elbert County, Colorado. August 29 to September 3, 1881. 30-centimetre theodolite, No. 108. Telescope above ground 1·90 metres. O. H. Tittmann, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
190	Adobe	0	00	00·00	+0·08	00·08	+0·40	00·48
191	Hugo	69	40	20·01	−0·11	19·90	−0·82	19·08
192	Overland	115	08	24·65	+0·01	24·66	+0·14	24·80
193	Eureka	167	53	52·09	+0·09	52·18	−0·12	52·06
194	Kit Carson	224	40	46·29	−0·06	46·23	+0·40	46·63

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·21.

Overland, Lincoln County, Colorado. September 12 to September 21, 1881. 30-centimetre theodolite, No. 108. Telescope above ground 1·75 metres. O. H. Tittmann and G. F. Bird, observers.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
	Azimuth Mark	0	00	00·00	....	....	....	00·00
195	Eureka	104	10	37·52	−0·05	37·47	+0·17	37·64
196	Kit Carson	144	03	39·02	−0·08	38·94	−0·34	38·60
197	Aroya	182	06	29·08	+0·01	29·09	−0·17	28·92
198	Adobe	219	50	30·14	+0·10	30·24	+0·02	30·26
199	Hugo	277	58	13·89	−0·03	13·86	+0·32	14·18

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·20.

Hugo, Lincoln County, Colorado. October 29 to November 8, 1880. 30-centimetre theodolite, No. 108. Telescope above ground 1·91 metres. O. H. Tittmann, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″
200	Overland	0	00	00·00	−0·03	59·97	−0·15	59·82
201	Aroya	38	40	10·31	−0·10	10·21	+0·62	10·83
202	Adobe	86	51	30·27	+0·02	30·29	−0·25	30·04
203	Square Bluffs	130	05	35·26	+0·11	35·37	−0·39	34·98
204	Holt	166	31	20·53	+0·02	20·55	+0·17	20·72

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·10.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895*—Continued.

Adobe, Lincoln County, Colorado. July 23 to August 10, 1881. 30-centimetre theodolite, No. 108. Telescope above ground 5·61 metres. O. H. Tittmann, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
	Mark	0	00	00·00	....	....	....	00·00
207	Hugo	4	35	07·28	+0·02	07·30	−0·20	07·10
208	Overland	39	35	56·41	+0·11	56·52	−0·19	56·33
209	Aroya	66	43	33·12	+0·07	33·19	−0·40	32·79
205	Cramers Gulch	254	09	13·00	+0·06	13·06	−0·64	12·42
206	Square Bluffs	309	09	14·70	−0·11	14·59	+1·43	16·02

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″ 28.

Square Bluffs, Lincoln County, Colorado. September 20 to September 27, 1880. 30-centimetre, theodoltite No. 108. Telescope above ground 1·88 metres. O. H. Tittmann, observer.

		°	′	″	″	″	″	″
210	Holt	0	00	00·00	−0·11	$\overline{59}$·89	−0·23	$\overline{59}$·66
211	Hugo	78	24	58·51	+0·11	58·62	+1·16	59·78
212	Adobe	159	45	07·69	−0·10	07·59	−1·00	06·59
213	Cramers Gulch	228	06	18·38	+0·06	18·44	+0·15	18·59
214	Big Springs	284	02	36·25	+0·07	36·32	−0·08	36·24
215	Holcolm Hills	322	24	10·13	−0·10	10·03	0·00	10·03

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·22.

Holt, Elbert County, Colorado. October 1 to October 17, 1880. 30-centimetre theodolite, No. 108. Telescope above ground 1·83 metres. O. H. Tittmann, observer.

		°	′	″	″	″	″	″
216	Hugo	0	00	00·00	+0·02	00·02	−0·67	$\overline{59}$·35
217	Square Bluffs	65	09	15·58	−0·10	15·48	+0·24	15·72
218	Holcolm Hills	178	19	13·43	−0·04	13·47	+0·43	13·90

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·96.

Cramers Gulch, Lincoln, County, Colorado. September 8 to September 14, 1880. 30-centimetre theodolite, No. 108. Telescope above ground 1·86 metres. O. H. Tittmann, observer. September 7 to September 14, 1895. 30-centimetre theodolite No. 118. Telescope above ground 6·22 metres. F. D. Granger, observer.

		°	′	″	″	″	″	″
219	Big Springs	0	00	00·00	−0·11	$\overline{59}$·89	−0·33	$\overline{59}$·56
220	Square Bluffs	74	58	25·87	+0·06	25·93	+0·19	26·12
221	Adobe	131	37	12·50	+0·06	12·56	+0·14	12·70
	Dry Camp	319	47	03·93	+0·03	03·96	....	....

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·06 in 1880 and ± 0″·47 in 1895.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustments, 1880 to 1895*—Completed.

Holcolm Hills, El Paso County, Colorado. July 20 to August 16, 1880. 30-centimetre theodolite, No. 108. O. H. Tittmann, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
222	Holt	0	00	00·00	+0·03	00·03	....	−0·80	59·23
223	Square Bluffs	29	14	12·37	−0·08	12·29	....	+0·83	13·12
	Big Springs	86	36	27·88	−0·05	27·83	−0·370	....	27·460
	Corral Bluffs	156	28	04·74	+0·12	04·86	+0·457	....	05·317
	El Paso East Base	165	48	35·85	+0·09	35·94	−0·190	....	35·730
	El Paso West Base	181	38	58·15	+0·03	58·18	+0·265	....	58·445
	Divide	212	10	36·84	−0·11	36·73	−0·162	....	36·568

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) = ± 0″·81.

Big Springs, El Paso County, Colorado. August 21 to September 3, 1880. 30-centimetre theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers. June 23 to July 6, 1895. 30-centimetre theodolite, No. 118. F. D. Granger and J. B. Boutelle, observers.

No. of direction.	Objects observed.	°	′	″	Reduction to sea level. ″	Resulting seconds. ″	Corrections from base-net adjustment. ″	Corrections from base-net and figure adjustment. ″	Final seconds in triangulation. ″
	Corral Bluffs	0	00	00·000	−0·10	59·90	+0·002	....	59·902
	El Paso East Base	27	23	27·51	−0·13	27·38	−0·268	....	27·112
	Divide	33	35	42·180	−0·137	42·043	−0·370	....	41·673
	Holcolm Hills	54	42	04·99	−0·05	04·94	+0·636	....	05·576
224	Square Bluffs	138	58	19·83	+0·06	19·89	....	+0·31	20·20
225	Cramers Gulch	188	03	38·61	−0·10	38·51	....	−0·08	38·43
	Dry Camp	235	37	57·12	−0·04	57·08	....	....	....
	Plateau	279	28	24·329	+0·101	24·430	....	....	....
	Pikes Peak	344	22	41·563	0·083	41·480	....	....	....

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·42 in 1880 and ± 0″·77 in 1895.

(*c*) *Figure adjustment.*

Observation equations.

No.	
1	$0 = -0·98 + (2) - (6) - (7) + (8)$
2	$0 = -0·94 + (1) - (4) - (13) + (14)$
3	$0 = -0·86 - (1) + (2) - (7) + (10) - (12) + (13)$
4	$0 = -1·73 - (3) + (6) - (8) + (9) - (21) + (22)$
5	$0 = -0·52 - (3) + (4) - (14) + (15) \quad (20) + (22)$
6	$0 = +0·44 - (9) + (11) - (19) + (21) - (23) + (26)$
7	$0 = -0·88 - (5) + (6) - (8) + (11) - (23) + (24)$
8	$0 = +0·56 - (10) + (11) + (12) - (16) - (23) + (25)$
9	$0 = +0·91 - (17) + (19) - (26) + (27) - (34) + (35)$
10	$0 = -0·10 - (27) + (29) - (33) + (34) - (36) + (38)$
11	$0 = +1·40 - (17) + (18) - (33) + (35) - (37) + (38)$
12	$0 = +0·17 - (32) + (33) - (38) + (40) - (46) + (48)$

(*c*) *Figure adjustment*—Continued.

Observation equations—Continued.

No.	
13	$0 = +0.05 - (28) + (29) - (36) + (40) - (46) + (47)$
14	$0 = -1.62 - (39) + (40) - (43) + (44) - (46) + (49)$
15	$0 = +0.12 - (30) + (32) - (48) + (50) - (56) + (58)$
16	$0 = -1.27 - (41) + (43) - (49) + (50) - (56) + (57)$
17	$0 = +1.72 - (30) + (31) + (41) + (45) - (57) + (58)$
18	$0 = 1.35 - (41) + (42) - (55) + (57) - (60) + (61)$
19	$0 = +2.22 - (53) + (55) - (61) + (62) - (67) + (69)$
20	$0 = +0.06 - (50) + (51) - (53) + (56) - (68) + (69)$
21	$0 = +0.25 - (51) + (52) - (59) + (62) - (67) + (68)$
22	$0 = 1.30 - (54) + (55) - (61) + (63) - (72) + (73)$
23	$0 = 0.67 - (53) + (54) - (66) + (69) - (73) + (74)$
24	$0 = 0.26 - (63) + (64) - (71) + (72) - (75) + (76)$
25	$0 = 0.03 - (70) + (71) - (76) + (77) - (82) + (83)$
26	$0 = -0.25 - (65) + (66) + (70) - (74) - (83) + (84)$
27	$0 = +0.14 - (77) + (79) - (81) + (82) - (85) + (86)$
28	$0 = -0.91 - (80) + (81) - (86) + (87) - (92) + (94)$
29	$0 = -1.41 - (78) + (79) - (85) + (87) - (92) + (93)$
30	$0 = -0.50 - (87) + (89) - (91) + (92) - (95) + (96)$
31	$0 = +0.13 - (87) + (88) - (90) + (92) - (103) + (104)$
32	$0 = +1.74 - (90) + (91) - (96) + (97) - (102) + (104)$
33	$0 = -0.04 - (97) + (98) - (100) + (102) - (108) + (109)$
34	$0 = 0.41 - (97) + (99) - (101) + (102) - (110) + (111)$
35	$0 = -0.45 - (98) + (99) - (107) + (108) - (110) + (112)$
36	$0 = +0.64 - (106) + (107) - (112) + (114) - (115) + (116)$
37	$0 = +1.31 - (105) + (106) - (116) + (117) - (123) + (125)$
38	$0 = -0.25 - (113) + (114) - (115) + (117) - (123) + (124)$
39	$0 = 0.57 - (117) + (119) - (122) + (123) - (126) + (127)$
40	$0 = +0.34 - (117) + (118) - (120) + (123) - (135) + (136)$
41	$0 = -0.20 - (120) + (122) - (127) + (128) - (134) + (136)$
42	$0 = -0.95 - (121) + (122) - (127) + (130) - (137) + (138)$
43	$0 = +0.86 - (120) + (121) - (133) + (136) - (138) + (139)$
44	$0 = 0.55 - (131) + (133) - (139) + (140) - (146) + (148)$
45	$0 = -0.48 - (128) + (129) - (131) + (134) - (147) + (148)$
46	$0 = -0.33 - (140) + (142) - (145) + (146) - (149) + (151)$
47	$0 = +0.38 - (132) + (133) - (139) + (142) - (149) + (150)$
48	$0 = -0.54 - (143) + (145) - (151) + (152) - (157) + (158)$
49	$0 = -1.36 - (152) + (153) - (156) + (157) - (159) + (161)$
50	$0 = -1.98 - (143) + (144) - (156) + (158) - (160) + (161)$
51	$0 = -0.20 - (155) + (156) - (161) + (163) - (165) + (166)$
52	$0 = 0.95 - (154) + (156) - (161) + (162) - (173) + (174)$
53	$0 = +0.13 - (154) + (155) - (166) + (167) - (172) + (174)$
54	$0 = +1.57 - (162) + (164) - (171) + (173) - (175) + (177)$
55	$0 = -2.85 - (163) + (164) + (165) - (168) - (175) + (176)$

(*c*) *Figure adjustment*—Continued.

Observation equations—Continued.

No.	
56	$0 = -0.42 - (170) + (171) - (177) + (179) - (185) + (186)$
57	$0 = -0.33 - (178) + (179) - (182) + (183) - (185) + (187)$
58	$0 = -1.19 - (169) + (170) - (182) + (184) - (186) + (187)$
59	$0 = -1.03 - (180) + (182) - (187) + (188) - (193) + (194)$
60	$0 = +1.59 - (181) + (182) - (187) + (189) - (195) + (196)$
61	$0 = +1.00 - (188) + (189) - (192) + (193) - (195) + (197)$
62	$0 = -2.21 - (191) + (192) - (197) + (199) - (200) + (201)$
63	$0 = +0.28 - (190) + (192) - (197) + (198) - (208) + (209)$
64	$0 = -0.20 - (198) + (199) - (200) + (202) - (207) + (208)$
65	$0 = +3.92 - (202) + (203) - (206) + (207) - (211) + (212)$
66	$0 = -2.85 - (203) + (204) - (210) + (211) - (216) + (217)$
67	$0 = -1.59 + (210) - (215) - (217) + (218) - (222) + (223)$
68	$0 = -3.17 - (205) + (206) - (212) + (213) - (220) + (221)$
69	$0 = +0.10 - (213) + (214) - (219) + (220) - (224) + (225)$
70	$0 = +0.43 - (214) + (215) - (223) + (224)$
71	$0 = -11.0 + 5.97(1) - 4.67(2) - 1.93(4) + 3.96(6) - 4.70(12) + 5.53(13) - 0.83(14)$
72	$0 = +60.7 - 3.59(3) + 14.37(4) - 10.78(5) - 1.33(19) + 3.65(20) - 2.32(22) - 13.77(24)$
	$+ 17.40(25) - 3.63(26)$
73	$0 = +167.9 - 62.12(9) + 63.54(10) - 1.42(11) - 1.33(19) + 58.50(20) - 57.17(21) - 3.33(23)$
	$- 6.96(25) - 3.63(26)$
74	$0 = +17.3 - 3.59(3) + 5.52(4) - 1.93(6) - 1.02(8) + 2.44(10) - 1.42(11) - 1.33(19) + 3.65(20)$
	$- 2.32(22) - 3.33(23) + 6.96(25) - 3.63(26)$
75	$0 = -4.5 - 1.69(17) + 2.03(18) - 0.34(19) - 4.19(26) + 5.64(27) - 1.45(29) - 0.14(36)$
	$+ 4.88(37) - 4.74(38)$
76	$0 = -1.0 - 1.45(27) + 8.22(28) - 6.77(29) - 1.66(32) + 4.34(33) - 2.68(34) - 8.77(46)$
	$+ 9.94(47) - 1.17(48)$
77	$0 = -3.4 - 2.64(31) + 2.61(32) + 0.03(33) - 4.77(38) + 6.99(39) - 2.22(40) - 0.28(46)$
	$+ 5.37(48) - 5.09(49)$
78	$0 = +50.3 - 5.50(30) + 8.11(31) - 2.61(32) - 5.37(48) + 8.35(49) - 2.98(50) - 1.90(56)$
	$+ 9.48(57) - 7.58(58)$
79	$0 = -5.3 + 0.25(41) + 4.41(42) - 4.66(43) - 4.05(55) + 5.95(56) - 1.90(57) - 1.76(59)$
	$+ 2.29(60) \quad 0.53(61)$
80	$0 = -7.4 - 0.49(50) + 2.17(51) - 1.68(52) - 0.76(53) + 4.81(55) - 4.05(56) - 5.27(67)$
	$+ 6.08(68) - 0.81(69)$
81	$0 = +5.7 + 3.14(53) - 3.90(54) + 0.76(55) + 2.43(61) - 4.24(62) + 1.81(63) + 0.67(72)$
	$- 4.63(73) + 3.96(74)$
82	$0 = +9.6 - 1.81(62) + 4.52(63) - 2.71(64) - 5.32(65) + 6.61(66) - 1.29(67) - 0.72(75)$
	$+ 2.98(76) - 2.26(77) - 2.01(82) + 5.32(83) - 3.31(84)$
83	$0 = +3.7 - 0.48(77) + 2.54(78) - 2.06(79) - 1.38(80) + 3.52(81) - 2.14(82) - 2.78(92)$
	$+ 3.44(93) - 0.66(94)$
84	$0 = -6.6 - 2.15(87) + 3.59(88) - 1.44(89) - 2.98(95) + 4.48(96) - 1.50(97) + 0.02(102)$
	$+ 4.38(103) - 4.40(104)$

(*c*) *Figure adjustment*—Continued.

Observation equations—Continued.

No.

85 $0 = -1.9 + 0.65(97) - 4.15(98) + 3.50(99) + 4.12(100) - 4.87(101) + 0.75(102) + 0.41(110)$
$- 1.77(111) + 1.36(112)$

86 $0 = +1.2 - 0.99(105) + 2.99(106) - 2.00(107) - 5.37(115) + 4.34(116) + 1.03(117) - 3.08(123)$
$+ 7.48(124) - 4.40(125)$

87 $0 = -6.1 + 5.40(117) - 6.67(118) + 1.27(119) + 1.92(126) - 4.08(127) + 2.16(128) + 0.92(134)$
$- 5.80(135) + 4.88(136)$

88 $0 = +8.5 + 2.75(120) - 3.55(121) + 0.80(122) + 2.16(127) - 3.55(128) + 1.39(130) + 0.98(137)$
$- 4.63(138) + 3.65(139)$

89 $0 = -0.3 + 3.02(128) - 4.41(129) + 1.39(130) + 0.98(137) - 3.12(139) + 2.14(140) + 0.35(146)$
$- 2.41(147) + 2.06(148)$

90 $0 = +6.2 - 1.49(131) + 5.76(132) - 4.27(133) - 2.28(145) + 2.63(146) - 0.35(148) - 2.20(149)$
$+ 3.98(150) - 1.78(151)$

91 $0 = -0.4 - 0.09(140) + 6.50(141) - 6.41(142) - 0.76(143) + 3.04(145) - 2.28(146) + 4.57(149)$
$- 4.57(152) + 1.64(157) - 1.64(158)$

92 $0 = -1.1 - 0.76(143) + 4.30(144) - 3.54(145) - 2.05(156) + 3.69(157) - 1.64(158) - 3.02(159)$
$+ 3.96(160) - 0.94(161)$

93 $0 = -17.3 - 3.23(154) + 7.25(155) - 4.02(156) - 0.32(161) + 10.43(162) - 10.11(163)$
$- 13.15(172) + 14.47(173) - 1.32(174)$

94 $0 = +0.1 - 3.23(154) + 7.25(155) - 4.02(156) - 0.32(161) + 7.42(163) - 7.10(164) - 1.90(171)$
$+ 3.22(172) - 1.32(174) - 7.37(175) + 7.74(176) - 0.37(177)$

95 $0 = +5.5 + 0.35(169) + 2.33(170) - 2.68(171) - 2.40(182) + 6.33(183) - 3.93(184) - 3.54(185)$
$+ 3.85(186) - 0.31(187)$

96 $0 = +3.7 + 2.45(180) - 3.32(181) + 0.87(182) + 1.44(187) - 3.25(188) + 1.81(189) + 0.45(195)$
$- 2.69(196) + 2.24(197)$

97 $0 = +4.9 + 2.94(197) - 2.72(198) - 0.22(199) + 2.64(200) - 4.53(201) + 1.89(202) + 1.11(207)$
$- 4.11(208) + 3.00(209)$

98 $0 = -12.9 - 2.24(202) + 5.09(203) - 2.85(204) - 1.48(205) + 2.93(206) - 1.45(207) - 0.98(216)$
$+ 0.08(217) + 0.90(218) - 0.57(219) + 1.95(220) - 1.38(221) - 3.76(222) + 5.10(223)$
$+ 2.03(224) - 1.82(225)$

99 $0 = -5.7 + 1.30(2) - 0.46(3) + 0.46(6) + 0.54(7) - 0.54(8) - 1.32(9) + 1.32(11) - 0.34(17)$
$+ 0.34(19) + 2.50(21) - 2.50(22) + 1.10(23) - 1.10(26) - 1.45(27) + 1.45(29) - 1.22(30)$
$+ 1.22(32) + 0.66(34) - 0.66(35) + 0.14(36) - 1.02(38) + 0.88(40) + 1.17(46) - 1.17(48)$
$- 0.49(50) + 0.49(52) - 0.76(53) + 0.76(55) + 1.05(56) - 1.05(58) + 0.53(59) - 0.53(61)$
$- 2.71(63) + 2.71(64) - 1.29(66) + 2.10(67) - 0.81(69) + 0.03(70) - 0.03(71) + 0.67(72)$
$- 0.67(74) + 0.72(75) - 0.72(76) - 0.48(77) + 0.48(79) - 1.38(80) + 1.38(81) + 2.01(82)$
$- 2.01(83) + 1.30(85) - 1.30(86) - 1.44(87) + 1.44(89) - 3.02(90) + 3.02(91) + 0.66(92)$
$- 0.66(94) + 2.98(95) - 2.98(96) - 3.50(98) + 3.50(99) - 0.75(100) + 0.73(102) + 0.02(104)$
$- 0.99(105) + 0.99(107) + 2.83(108) - 2.83(109) + 0.41(110) - 0.41(112) - 3.74(113)$
$+ 3.74(114) - 1.03(115) - 0.24(117) + 1.27(119) - 0.80(120) + 0.80(122) + 4.40(124)$
$- 4.40(125) + 1.92(126) - 1.92(127) - 1.39(128) + 1.39(130) - 1.49(131) + 1.49(133)$
$+ 0.92(134) - 0.92(136) + 0.98(137) - 0.98(139) - 0.09(140) + 0.09(142) - 0.76(143)$
$+ 0.76(145) + 0.35(146) - 0.35(148) + 1.78(149) - 1.78(151) - 0.85(152) + 0.85(153)$
$- 1.18(154) + 1.18(156) + 1.64(157) - 1.64(158) + 0.94(159) - 0.94(161) - 3.97(162)$

(*c*) *Figure adjustment*—Continued.

Observation equations—Continued.

No.	
99	$+3{\cdot}97(164)+0{\cdot}35(169)-0{\cdot}35(171)+1{\cdot}79(173)-1{\cdot}79(174)-0{\cdot}22(175)+0{\cdot}22(177)$
	$-1{\cdot}36(178)+1{\cdot}36(179)-0{\cdot}87(180)+0{\cdot}87(182)+3{\cdot}93(183)-3{\cdot}93(184)+0{\cdot}31(185)$
	$-0{\cdot}31(187)-1{\cdot}81(188)+1{\cdot}81(189)-0{\cdot}78(190)+0{\cdot}78(191)+1{\cdot}38(193)-1{\cdot}38(194)$
	$+0{\cdot}45(195)-0{\cdot}23(197)-0{\cdot}22(199)+2{\cdot}64(200)-2{\cdot}64(201)-2{\cdot}24(202)+2{\cdot}24(203)$
	$-1{\cdot}48(205)+1{\cdot}48(206)+1{\cdot}11(207)-1{\cdot}11(209)+0{\cdot}32(211)-0{\cdot}32(212)-2{\cdot}66(214)$
	$+2{\cdot}66(215)-0{\cdot}57(219)+1{\cdot}95(220)-1{\cdot}38(221)+1{\cdot}34(223)+1{\cdot}82(224)-1{\cdot}82(225)$

Correlate equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{11}	C_{71}	C_{72}	C_{73}	C_{74}	C_{75}	C_{99}
(1)		+1	−1								+5·97					
(2)	+1		+1								−4·67					+1·30
(3)				−1	−1							−3·59		−3·59		−0·46
(4)		−1			+1						−1·93	+14·37		+5·52		
(5)	....	....	....	....	....	....	−1	....	....	....	....	−10·78	....	....	....	....
(6)	−1			+1			+1				+3·96			−1·93		+0·46
(7)	−1		−1													+0·54
(8)	+1			−1			−1							−1·02		−0·54
(9)				+1		−1							−62·12			−1·32
(10)	....	....	+1	....	....	....	....	−1	....	....	....	....	+63·54	+2·44	....	....
(11)						+1	+1	+1					−1·42	−1·42		+1·32
(12)			−1					+1			−4·70					
(13)		−1	+1								+5·53					
(14)		+1			−1						−0·83					
(15)	....	....	....	....	+1	....	....	....	....	....	....	....	....	....	....	....
(16)								−1								
(17)									−1	−1					−1·69	−0·34
(18)										+1					+2·03	
(19)									+1			−1·33	−1·33	−1·33	−0·34	+0·34
(20)	....	....	....	....	−1	....	....	....	....	....	....	+3·65	+58·50	+3·65	....	....
(21)				−1		+1							−57·17			+2·50
(22)				+1	+1							−2·32		−2·32		−2·50

Correlate equations—Continued.

	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{17}	C_{72}	C_{73}	C_{74}	C_{75}	C_{76}	C_{77}	C_{78}	C_{99}
(23)	−1	−1	−1										−3·33	−3·33					+1·10
(24)		+1										−13·77							
(25)			+1									+17·40	+6·96	+6·96					
(26)	+1			−1								−3·63	−3·63	−3·63	−4·19				−1·10
(27)	....	....	....	+1	−1	....	....	....	....	....	....	....	....	....	+5·64	−1·45	....	....	−1·45
(28)								−1								+8·22			
(29)					+1			+1							−1·45	−6·77			+1·45
(30)										−1	−1							−5·50	1·22
(31)											+1						−2·64	+8·11	
(32)	....	....	....	....	....	....	−1	....	....	+1	....	....	....	....	....	−1·66	+2·61	−2·61	+1·22
(33)					−1	−1	+1									+4·34	+0·03		
(34)				−1	+1											−2·68			+0·66
(35)				+1		+1													−0·66
(36)					−1			−1							−0·14				+0·14
(37)	....	....	....	.. .	....	−1	....	....	....	....	....	....	....	....	+4·88	....	....	....	....
(38)					+1	+1	−1								−4·74		−4·77		−1·02
(39)									−1								+6·99		
(40)							+1	+1	+1								−2·22		+0·88

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C76	C77	C78	C79	C80	C81	C99
(41)					−1	+1	−1									+0.25			
(42)							+1									+4.41			
(43)			−1		+1											−4.66			
(44)			+1																
(45)	...	...	...	...	...	−1	...	...	...	...	...	...	......	......	......	......	......	......	......
(46)	−1	−1	−1										−8.77	−0.28					+1.17
(47)		+1											+9.94						
(48)	+1			−1									−1.17	+5.37	−5.37				−1.17
(49)			+1		−1									−5.09	+8.35				
(50)	...	...	...	+1	+1	...	...	...	−1	...	...	...	......	......	−2.98	......	−0.49	......	−0.49
(51)									+1	−1							+2.17		
(52)										+1							−1.68		+0.49
(53)								−1	−1			−1					−0.76	+3.14	−0.76
(54)											−1	+1						−3.90	
(55)	...	. .	...	...	...	...	−1	+1	...	...	+1	...	......	......	......	−4.05	+4.81	+0.76	+0.76
(56)				−1	−1				+1						−1.90	+5.95	−4.05		+1.05
(57)					+1	−1	+1								+9.48	−1.90			
(58)				+1		+1									−7.58				−1.05

Correlate equations—Continued.

	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C29	C79	C80	C81	C82	C83	C99
(59)				−1								−1.76					+0.53
(60)	−1											+2.29					
(61)	+1	−1			−1							−0.53		+2.43			−0.53
(62)		+1		+1										−4.24	−1.81		
(63)	...	...	...	...	+1	...	−1	...	...	...	...	......	......	+1.81	+4.52	......	−2.71
(64)							+1								−2.71		+2.71
(65)									−1						−5.32		
(66)						−1			+1						+6.61		−1.29
(67)		−1		−1									−5.27		−1.29		+2.10
(68)	...	...	−1	+1	...	...	...	. .	...	...	...	......	+6.08	......	......	......	......
(69)		+1	+1			+1							−0.81				−0.81
(70)								−1	+1								+0.03
(71)							−1	+1									−0.03
(72)					−1		+1							+0.67			+0.67
(73)	...	...	...	...	+1	−1	...	...	...	...	...	......	......	−4.63	......	......	......
(74)						+1			−1					+3.96			−0.67
(75)							−1								−0.72		+0.72
(76)							+1	−1							+2.98		−0.72
(77)								+1		−1					−2.26	−0.48	−0.48
(78)	...	...	...	...	...	...	...	...	...	...	−1	......	......	......	......	+2.54	......
(79)										+1	+1					−2.06	+0.48

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

	C_{25}	C_{26}	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{82}	C_{83}	C_{84}	C_{85}	C_{99}
(80)				−1									−1·38			−1·38
(81)			−1	+1									+3·52			+1·38
(82)	−1		+1									−2·01	−2·14			+2·01
(83)	+1	−1										+5·32				−2·01
(84)	....	+1	....	....	....	....	....	....	....	....	....	−3·31	....	....	....	....
(85)			−1		−1											+1·30
(86)			+1	−1												−1·30
(87)				+1	+1	−1	−1							−2·15		−1·44
(88)							+1							+3·59		
(89)	....	....	....	....		+1	....	....	....	....	....	....	....	−1·44	....	+1·44
(90)							−1	−1								−3·02
(91)						−1		+1								+3·02
(92)				−1	−1	+1	+1						−2·78			+0·66
(93)					+1								+3·44			
(94)	....	....	....	+1	....	....	....	....	....	....	....	....	−0·66	....	....	−0·66
(95)						−1								−2·98		+2·98
(96)						+1		−1						+4·48		−2·98
(97)								+1	−1	−1				−1·50	+0·65	
(98)									+1		−1				−4·15	−3·50
(99)	....	....	....	....	....	....	....	....	....	+1	+1	....	....	....	+3·50	+3·50
(100)									−1						+4·12	−0·75
(101)										−1					−4·87	
(102)								−1	+1	+1				+0·02	+0·75	+0·73
(103)							−1							+4·38		
(104)	....	....	....	....	....	....	+1	+1	....	....	....	....	....	−4·40	....	+0·02

Correlate equations—Continued.

	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{39}	C_{40}	C_{41}	C_{42}	C_{43}	C_{45}	C_{85}	C_{86}	C_{87}	C_{88}	C_{89}	C_{99}
(105)					−1									−0·99				−0·99
(106)				−1	+1									+2·99				
(107)			−1	+1										−2·00				+0·99
(108)	−1		+1															+2·83
(109)	+1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	−2·83
(110)		−1	−1										+0·41					+0·41
(111)		+1											−1·77					
(112)			+1	−1									+1·36					−0·41
(113)						−1												−3·74
(114)	....	....	....	+1	....	+1	....	....	....	....	....	....	....	....	....	....	....	+3·74
(115)				−1		−1								−5·37				−1·03
(116)				+1	−1									+4·34				
(117)					+1	+1	−1	−1						+1·03	+5·40			−0·24
(118)								+1							−6·67			
(119)	....	....	....	....	....	....	+1	....	....	....	....	....	....	....	+1·27	....	....	+1·27
(120)								−1	−1		−1					+2·75		−0·80
(121)										−1	+1					−3·55		
(122)							−1		+1	+1						+0·80		+0·80
(123)					−1	−1	+1	+1						−3·08				
(124)	....	....	....	....	....	+1	....	....	....	....	....	....	....	+7·48	....	....	....	+4·40
(125)					+1									−4·40				−4·40
(126)							−1								+1·92			+1·92
(127)							+1		−1	−1					−4·08	+2·16		−1·92
(128)									+1			−1			+2·16	−3·55	+3·02	−1·39
(129)												+1					−4·41	
(130)	....	....	...	....	....	....	....	....	....	+1	....	....	....	....	....	+1·39	+1·39	+1·39

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

	C_{40}	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}	C_{47}	C_{48}	C_{49}	C_{50}	C_{87}	C_{88}	C_{89}	C_{90}	C_{91}	C_{92}	C_{99}
(131)					−1	−1									−1·49			−1·49
(132)								−1							+5·76			
(133)				−1	+1			+1							−4·27			+1·49
(134)		−1				+1						+0·92						+0·92
(135)	−1											−5·80						
(136)	+1	+1		+1								+4·88						−0·92
(137)			−1										+0·98	+0·98				+0·98
(138)			+1	−1									−4·63					
(139)				+1				−1					+3·65	−3·12				−0·98
(140)					+1		−1							+2·14		−0·09		−0·09
(141)																+6·50		
(142)							+1	+1								−6·41		+0·09
(143)									−1		−1					−0·76	−0·76	−0·76
(144)											+1						+4·30	
(145)							−1		+1						−2·28	+3·04	−3·54	+0·76
(146)					−1		+1							+0·35	+2·63	−2·28		+0·35
(147)						−1								−2·41				
(148)					+1	+1								+2·06	−0·35			−0·35
(149)							−1	−1							−2·20	+4·57		+1·78
(150)								+1							+3·98			
(151)							+1		−1						−1·78			−1·78
(152)									+1	−1						−4·57		−0·85
(153)										+1								+0·85

Correlate equations—Continued.

	C_{48}	C_{49}	C_{50}	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}	C_{56}	C_{57}	C_{58}	C_{91}	C_{92}	C_{93}	C_{94}	C_{95}	C_{99}
(154)					−1	−1								−3·23	−3·23		−1·18
(155)				−1		+1								+7·25	+7·25		
(156)		−1	−1	+1	+1								−2·05	−4·02	−4·02		+1·18
(157)	−1	+1										+1·64	+3·69				+1·64
(158)	+1		+1									−1·64	−1·64				−1·64
(159)		−1											−3·02				+0·94
(160)			−1										+3·96				
(161)		+1	+1	−1	−1								−0·94	−0·32	−0·32		−0·94
(162)					+1		−1							+10·43			−3·97
(163)				+1				−1						−10·11	+7·42		
(164)							+1	+1							−7·10		+3·97
(165)				−1				+1									
(166)				+1		−1											
(167)						+1											
(168)								−1									
(169)											−1					+0·35	+0·35
(170)									−1		+1					+2·33	
(171)							−1		+1						−1·90	−2·68	−0·35
(172)						−1								−13·15	+3·22		
(173)					−1		+1							+14·47			+1·79
(174)					+1	+1								−1·32	−1·32		−1·79
(175)							−1	−1							−7·37		−0·22
(176)								+1							+7·74		
(177)							+1		−1						−0·37		+0·22
(178)										−1							−1·36
(179)									+1	+1							+1·36

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

	C_{56}	C_{57}	C_{58}	C_{59}	C_{60}	C_{61}	C_{62}	C_{63}	C_{64}	C_{65}	C_{66}	C_{95}	C_{96}	C_{97}	C_{98}	C_{99}
(180)				−1									+2·45			−0·87
(181)					−1								−3·32			
(182)		−1	−1	+1	+1							−2·40	+0·87			+0·87
(183)		+1										+6·33				+3·93
(184)	....	....	+1	....	....	....	....	....	....	....	....	−3·93	....	....	--	−3·93
(185)	−1	−1										−3·54				+0·31
(186)	+1		−1									+3·85				
(187)		+1	+1	−1	−1							−0·31	+1·44			−0·31
(188)				+1		−1							−3·25			−1·81
(189)	....	....	....	....	+1	+1	....	....	....	....	....	....	+1·81	....	....	+1·81
(190)								−1								−0·78
(191)							−1									+0·78
(192)						−1	+1	+1								
(193)				−1		+1										+1·38
(194)	....	....	....	+1	....	....	....	....	...	....	....	....	....	....	....	−1·38
(195)					−1	−1							+0·45			+0·45
(196)					+1								−2·69			
(197)						+1	−1	−1					+2·24	+2·94		−0·23
(198)								+1	−1					−2·72		
(199)	....	....	....	....	....	....	+1	....	+1	....	....	....	....	−0·22	....	−0·22
(200)							−1		−1					+2·64		+2·64
(201)							+1							−4·53		−2·64
(202)									+1	−1				+1·89	−2·24	−2·24
(203)										+1	−1				+5·09	+2·24
(204)	....	....	....	....	....	....	....	...	....	....	+1	....	....	....	−2.85	....

Correlate equations—Completed.

	C_{63}	C_{64}	C_{65}	C_{66}	C_{67}	C_{68}	C_{69}	C_{70}	C_{97}	C_{98}	C_{99}
(205)						−1				−1·48	−1·48
(206)			−1			+1				+2·93	+1·48
(207)		−1	+1						+1·11	−1·45	+1·11
(208)	−1	+1							−4·11		
(209)	+1	....	....	....	....	....	....	....	+3·00	....	−1·11
(210)				−1	+1						
(211)			−1	+1							+0·32
(212)			+1			−1					−0·32
(213)						+1	−1				
(214)	....	....	...	....	....	....	+1	−1	....	....	−2·66
(215)					−1			+1			+2·66
(216)				−1						−0·98	
(217)				+1	−1					+0·08	
(218)					+1					+0·90	
(219)	....	....	....	....	....	....	−1	....	....	−0·57	−0·57
(220)						−1	+1			+1·95	+1·95
(221)						+1				−1·38	−1·38
(222)					−1					−3·76	
(223)	....	....	....	....	+1	....	....	−1	....	+5·10	+1·34
(224)							−1	+1		+2·03	+1·82
(225)							+1			−1·82	−1·82

(*c*) *Figure adjustment*—Continued.

Normal equations.

		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{71}	C_{72}	C_{73}	C_{74}	C_{75}	C_{76}	C_{99}
1	0=−0·98	+4		+2	−2			−2					−8·63			+0·91			−0·24
2	0=−0·94		+4	−2		−2							+1·54	−14·37		−5·52			
3	0=−0·86			+6					−2				−0·41		+63·54	+2·44			+0·76
4	0=−1·73				+6	+2	−2	+2					+3·96	+1·27	−4·95	+0·36			−4·86
5	0=−0·52	....	....	....	....	+6	....	....	....	....	....	....	−1·10	+11·99	−58·50	+3·14	....	....	−2·04
6	0=+0·44						+6	+2	+2	−2				−2·30	+4·56	−0·39	−3·85		+2·60
7	0=−0·88							+6	+2				+3·96	−2·99	+1·91	+1·00			+1·22
8	0=+0·56								+6				−4·70	+17.40	−54·67	+6·43			+0·22
9	0=+0·91									+6	−2	+2		+2·30	+2·30	+2·30	+11·18	+1·23	−0·99

Normal equations—Continued.

		C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{20}	C_{75}	C_{76}	C_{77}	C_{78}	C_{79}	C_{80}	C_{99}
10	0=−0·10	+6	+2	−2	+2							−11·69	−12·34	−4·80				+2·40
11	0=+1·40		+6	−2								−5·90	−4·34	−4·80				−1·34
12	0=+0·17			+6	+2	+2	−2					+4·74	+13·60	+5·62	−2·76			−1·66
13	0=+0·05				+6	+2						−1·31	+3·72	−1·94				+1·02
14	0=−1·62	....	....	....	....	+6	....	−2	....	....	....	....	+8·77	−14·02	+8·35	+4·66	....	−0·29
15	0=+0·12						+6	+2	+2		−2		−0·49	−2·76	−0·40	−5·95	+3·56	+1·02
16	0=−1·27							+6	−2	+2	−2			+5·09	+0·05	−12·76	+3·56	−1·54
17	0=+1·72								+6	−2				−2·64	−3·45	+2·15		+0·17

Normal equations—Continued.

		C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{78}	C_{79}	C_{80}	C_{81}	C_{82}	C_{83}	C_{99}
18	0=−1·35	+6	−2			−2						+9·48	+3·49	−4·81	+1·67			−1·29
19	0=+2·22		+6	+2	+2	+2	+2						−3·52	+10·03	−9·05	−0·52		−0·86
20	0=+0·06			+6	−2		+2					+1·08	+5·95	−7·52	−3·14			+1·49
21	0=+0·25				+6								+1·76	+7·50	−4·24	−0·52		−2·14
22	0=+1·30	....	....	....	....	+6	−2	−2	....	....	....	....	−3·52	+4·81	−1·26	+4·52	....	−2·09
23	0=−0·67						+6			−2				−0·05	+1·55	−6·61		+0·57
24	0=−0·26							+6	−2						−1·14	−3·53		+4·68
25	0=+0·03								+6	−2	−2					+2·09	+1·66	−3·84
26	0=+0·25									+6					−3·96	+3·30		+1·42

Normal equations—Continued.

		C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{82}	C_{83}	C_{84}	C_{85}	C_{86}	C_{99}
27	0=+0·14	+6	−2	+2										+0·25	−7·24				−1·01
28	0=−0·91		+6	+2	−2	−2									+7·02	−2·15			+1·30
29	0=+1·41			+6	−2	−2									+1·62	−2·15			−2·92
30	0=+0 50				+6	+2	−2								−2·78	+8·17			−5·44
31	0=+0·13	....	....	....	....	+6	+2	....	....	....	....	....	....	....	−2·78	−3·04	....	....	+5·14
32	0=+1·74						+6	−2	−2							−10·40	−0·10		+8·31
33	0=−0·04							+6	+2	−2						+1·52	−8·17		−7·68
34	0=−0·41								+6	+2						+1·52	+6·29		+3·82
35	0=+0·45									+6	−2						+8·60	+2·00	+8·02
36	0=+0·64	....	....	....	....	....	....	....	....	....	+6	−2	+2	....	....	....	−1·36	+4·72	+6·17

(*c*) *Figure adjustment*—Continued.

Normal equations—Continued.

		C_{37}	C_{38}	C_{39}	C_{40}	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}	C_{47}	C_{86}	C_{87}	C_{88}	C_{89}	C_{90}	C_{91}	C_{99}
37	0=+1·31	+6	+2	−2	−2								−0·65	+5·40					−3·65
38	0=−0·25		+6	−2	−2								+16·96	+5·40					+12·67
39	0=−0·57			+6	+2	−2	−2						−4·11	−10·13	+1·36				−3·13
40	0=+0·34				+6	+2		+2					−4·11	−1·39	−2·75				+0·12
41	0=−0·20	....	....	....	....	+6	+2	+2	....	−2	....	....	....	+10·20	−7·66	+3·02	....	....	+0·29
42	0=+0·95						+6	−2						+4·08	−2·03	+0·41			+3·13
43	0=+0·86							+6	−2			−2		+4·88	+1·98	−3·12	+4·27		−2·59
44	0=−0·55								+6	+2	−2	+2			−3·65	+6·97	−5·76	+2·19	+3·17
45	0=−0·48									+6				−1·24	+3·55	−2·96	+1·14		+3·45

Normal equations—Continued.

		C_{46}	C_{47}	C_{48}	C_{49}	C_{50}	C_{51}	C_{52}	C_{88}	C_{89}	C_{90}	C_{91}	C_{92}	C_{93}	C_{94}	C_{99}
46	0=+0·33	+6	+2	−2						−1·79	+5·33	−16·21	+3·54			−3·79
47	0=+0·38		+6						−3·65	+3·12	−3·85	−10·98				+0·78
48	0=−0·54			+6	−2	+2					−0·50	−4·05	−8·11			−0·83
49	0=−1·36				+6	+2	−2	−2				+6·21	+7·82	+3·70	+3·70	+0·28
50	0=−1·98	....	....	....	....	+6	−2	−2	....	....	....	−0·88	+0·57	+3·70	+3·70	−3·00

Normal equations—Continued.

		C_{51}	C_{52}	C_{53}	C_{54}	C_{55}	C_{56}	C_{57}	C_{58}	C_{59}	C_{60}	C_{61}	C_{92}	C_{93}	C_{94}	C_{95}	C_{96}	C_{99}
51	0=−0·20	+6	+2	−2		−2							−1·11	−21·06	−3·53			+2·12
52	0=−0·95		+6	+2	−2								−1·11	−5·83	−1·79			−4·25
53	0=+0·13			+6										+22·31	+5·94			−0·61
54	0=+1·57				+6	+2	−2							+4·04	+1·80	+2·68		+10·52
55	0=−2·85	....	....	....	....	+6	....	....	....	....	....	....	....	+10·11	+0·59	....	....	+4·19
56	0=−0·42						+6	+2	−2						−1·53	+2·38		+0·48
57	0=−0·33							+6	+2	−2	−2					+11·96	+0·57	+5·16
58	0=−1·19								+6	−2	−2					−3·71	+0·57	−5·46
59	0=−1·03									+6	+2	−2				−2·09	−6·27	−2·52
60	0=+1·59	....	....	....	....	....	....	....	....	....	+6	+2	....	....	....	−2·09	+1·42	+2·54

Normal equations—Continued.

		C_{61}	C_{62}	C_{63}	C_{64}	C_{65}	C_{66}	C_{67}	C_{68}	C_{69}	C_{70}	C_{96}	C_{97}	C_{98}	C_{99}
61	0=+1·00	+6	−2	−2								+6·85	+2·94		+4·32
62	0=−2·21		+6	+2	+2							−2·24	−10·33		−6·05
63	0=+0·28			+6	−2							−2·24	+1·45		−0·10
64	0=−0·20	....	....	....	+6	−2	....	....	....	....	....	....	−3·47	−0·79	−6·21
65	0=+3·92					+6	−2		−2				−0·78	+2·95	+3·47
66	0=−2·85						+6	−2						−6·88	−1·92
67	0=−1·59							+6			−2			+9·68	−1·32
68	0=−3·17								+6	−2				+1·08	−0·05
69	0=+0·10									+6	−2			−1·33	−3·78
70	0=+0·43	....	....	....	....	....	....	....	....	....	+4	....	....	−3·07	+5·80

(*c*) *Figure adjustment*—Completed.

Normal equations—Continued.

		C_{71}	C_{72}	C_{73}	C_{74}	C_{75}	C_{76}	C_{77}	C_{78}	C_{79}	C_{80}	C_{99}
71	o = − 11·0	+130·22	− 27·73		− 18·30							− 4·25
72	o = + 60·7		+861·62	+349·58	+246·96	+ 15·66						+10·99
73	o = +167·9			+14 663·38	+445·06	+ 15·66						−62·92
74	o = + 17·3				+149·28	+ 15·66						+ 5·12
75	o = − 4·5	....	....	....	....	+104·86	+ 1·64	+ 22·61	....	....	......	− 0·40
76	o = − 1·0						+321·36	− 8·03	+ 10·62			−20·40
77	o = − 3·4							+145·15	− 99·56			− 0·52
78	o = + 50·3								+361·21	−29·32	+9·16	+17·23

Normal equations—Continued.

		C_{79}	C_{80}	C_{81}	C_{82}	C_{83}	C_{84}	C_{85}	C_{86}	C_{87}	C_{88}	C_{89}	C_{99}
79	o = −5·3	+105·26	− 43·58	− 4·37									+ 2·52
80	o = −7·4		+113·28	+ 1·27	+ 6·80								−11·01
81	o = +5·7			+90·37	+ 15·86								−10·21
82	o = +9·6				+162·51	+ 5·39							−47·14
83	o = +3·7	....	....	....	....	+49·80	....	....	....	....	....	....	+ 0·30
84	o = −6·6						+89·33	− 0·96					−21·28
85	o = −1·9							+76·30					+23·84
86	o = +1·2								+147·45	+ 5·56			+56·56
87	o = −6·1									+158·56	−16·48	+ 6·52	+ 5·19
88	o = +8·5	....	....	....	....	....	....	....	....	....	+75·73	−19·22	− 1·46

Normal equations—Completed.

		C_{89}	C_{90}	C_{91}	C_{92}	C_{93}	C_{94}	C_{95}	C_{96}	C_{97}	C_{98}	C_{99}
89	o = − 0·3	+55·95	+ 0·20	− 0·99								+ 0·96
90	o = + 6·2		+89·72	− 22·98	+ 8·07							− 5·58
91	o = − 0·4			+145·51	− 1·44							+ 18·92
92	o = − 1·1				+77·80	+ 8·54	+ 8·54					+ 2·26
93	o = −17·3	....	....	....	......	+674·30	− 36·36	....	....	......	....	− 13·77
94	o = + 0·1						+314·81	+ 5·09				− 24·25
95	o = + 5·5							+101·46	− 2·53			+ 38·29
96	o = + 3·7								+46·15	+ 6·59		+ 7·02
97	o = + 4·9									+74·28	− 5·84	+ 11·97
98	o = −12·9	....	....	....	....	....	....	....	....	....	+107·31	+ 41·21
99	o = − 5·7											+417·57

Resulting values of correlates.

C_{1} = +0·817	C_{12} = −0·667	C_{23} = +0·715	C_{34} = +0·087
C_{2} = −0·080	C_{13} = −0·133	C_{24} = +0·243	C_{35} = −0·471
C_{3} = −0·054	C_{14} = +0·961	C_{25} = +0·291	C_{36} = −0·624
C_{4} = +0·513	C_{15} = −0·419	C_{26} = +0·172	C_{37} = −0·621
C_{5} = −0·044	C_{16} = +1·042	C_{27} = +0·272	C_{38} = +0·473
C_{6} = +0·022	C_{17} = +0·032	C_{28} = +0·474	C_{39} = +0·167
C_{7} = +0·111	C_{18} = −0·045	C_{29} = −0·473	C_{40} = −0·210
C_{8} = +0·017	C_{19} = −2·053	C_{30} = −0·460	C_{41} = +0·352
C_{9} = −0·166	C_{20} = +1·035	C_{31} = +0·261	C_{42} = −0·472
C_{10} = +0·042	C_{21} = +0·500	C_{32} = −0·527	C_{43} = −0·469
C_{11} = −0·350	C_{22} = +0·573	C_{33} = −0·299	C_{44} = −0·210

Resulting values of correlates—Completed.

C_{45} = +0·332	C_{59} = +0·456	C_{73} = −0·010 38	C_{87} = +0·047 4
C_{46} = −0·077	C_{60} = −0·453	C_{74} = +0·038	C_{88} = −0·126
C_{47} = −0·367	C_{61} = +0·281	C_{75} = +0·094 8	C_{89} = −0·025
C_{48} = −0·023	C_{62} = +0·851	C_{76} = +0·010 7	C_{90} = −0·088 3
C_{49} = +0·366	C_{63} = −0·431	C_{77} = −0·058 5	C_{91} = −0·063 9
C_{50} = +0·444	C_{64} = −0·518	C_{78} = −0·190 5	C_{92} = −0·012 2
C_{51} = +0·726	C_{65} = −0·604	C_{79} = +0·048 5	C_{93} = +0·033 2
C_{52} = −0·008	C_{66} = +0·540	C_{80} = +0·279 5	C_{94} = +0·006 5
C_{53} = +0·098	C_{67} = +0·314	C_{81} = −0·193 4	C_{95} = −0·069 7
C_{54} = −0·674	C_{68} = +0·382	C_{82} = −0·030	C_{96} = −0·043 1
C_{55} = +0·854	C_{69} = +0·234	C_{83} = −0·104	C_{97} = +0·026
C_{56} = −0·164	C_{70} = +0·202	C_{64} = +0·077 7	C_{96} = +0·128 7
C_{57} = +0·189	C_{71} = +0·111 1	C_{85} = +0·014 2	C_{99} = +0·043 8
C_{58} = +0·083	C_{72} = −0·076 8	C_{86} = −0·058 7	

Corrections to angular directions.

″	″	″	″
(1) = +0·637	(29) = −0·236	(57) = −0·933	(85) = +0·258
(2) = +0·301	(30) = +1·382	(58) = +1·011	(86) = −0·259
(3) = −0·349	(31) = −1·359	(59) = −0·562	(87) = −0·030
(4) = −1·072	(32) = +0·627	(60) = +0·155	(88) = +0·540
(5) = +0·717	(33) = −0·315	(61) = +0·916	(89) = −0·509
(6) = +0·194	(34) = +0·208	(62) = −0·679	(90) = +0·134
(7) = −0·739	(35) = −0·545	(63) = −0·275	(91) = +0·065
(8) = +0·130	(36) = +0·084	(64) = +0·443	(92) = +0·118
(9) = +1·078	(37) = +0·813	(65) = −0·012	(93) = −0·831
(10) = −0·638	(38) = +0·144	(66) = −0·798	(94) = +0·514
(11) = +0·169	(39) = −1·370	(67) = +0·211	(95) = +0·359
(12) = −0·451	(40) = +0·330	(68) = +1·164	(96) = +0·284
(13) = +0·640	(41) = −0·953	(69) = −0·564	(97) = −0·423
(14) = −0·128	(42) = +0·169	(70) = −0·118	(98) = −0·040
(15) = −0·044	(43) = −0·145	(71) = +0·047	(99) = −0·181
(16) = −0·017	(44) = +0·961	(72) = −0·431	(100) = +0·325
(17) = +0·341	(45) = −0·032	(73) = +0·753	(101) = −0·156
(18) = −0·158	(46) = −0·188	(74) = −0·252	(102) = +0·360
(19) = −0·140	(47) = −0·027	(75) = −0·189	(103) = +0·079
(20) = −0·704	(48) = +0·397	(76) = −0·169	(104) = −0·607
(21) = +0·211	(49) = −1·374	(77) = +0·116	(105) = +0·636
(22) = +0·450	(50) = −0·002	(78) = +0·209	(106) = −0·173
(23) = −0·194	(51) = +1·141	(79) = +0·034	(107) = +0·007
(24) = +1·169	(52) = +0·051	(80) = −0·390	(108) = −0·048
(25) = −1·127	(53) = −0·549	(81) = −0·104	(109) = −0·423
(26) = −0·078	(54) = +0·896	(82) = +0·352	(110) = +0·408
(27) = +0·247	(55) = −0·401	(83) = −0·129	(111) = +0·062
(28) = +0·221	(56) = −0·023	(84) = +0·271	(112) = +0·154

Corrections to angular directions—Completed.

"	"	"	"
(113) = −0·637	(142) = −0·030	(171) = +0·670	(200) = −0·148
(114) = +0·013	(143) = 0·396	(172) = −0·514	(201) = +0·617
(115) = +0·421	(144) = +0·392	(173) = −0·108	(202) = −0·251
(116) = −0·258	(145) = +0·137	(174) = 0·041	(203) = −0·391
(117) = +0·080	(146) = +0·053	(175) = −0·238	(204) = +0·173
(118) = −0·526	(147) = 0·272	(176) = +0·904	(205) = 0·637
(119) = +0·283	(148) = +0·087	(177) = −0·502	(206) = +1·428
(120) = −0·054	(149) = +0·424	(178) = −0·249	(207) = −0·195
(121) = +0·450	(150) = −0·718	(179) = +0·085	(208) = −0·194
(122) = −0·353	(151) = +0·025	(180) = −0·600	(209) = −0·402
(123) = +0·286	(152) = −0·134	(181) = +0·596	(210) = 0·226
(124) = +0·227	(153) = +0·403	(182) = −0·101	(211) = +1·158
(125) = −0·556	(154) = 0·270	(183) = 0·080	(212) = 1·000
(126) = +0·008	(155) = −0·340	(184) = +0·185	(213) = +0·148
(127) = −0·262	(156) = −0·174	(185) = +0·236	(214) = 0·085
(128) = +0·433	(157) = +0·311	(186) = −0·515	(215) = +0·005
(129) = +0·442	(158) = +0·474	(187) = +0·215	(216) = 0·666
(130) = −0·621	(159) = −0·288	(188) = −0·236	(217) = +0·236
(131) = −0·055	(160) = 0·492	(189) = −0·171	(218) = +0·430
(132) = −0·142	(161) = −0·049	(190) = −0·397	(219) = −0·332
(133) = +0·334	(162) = −0·838	(191) = −0·817	(220) = −0·188
(134) = +0·064	(163) = 0·416	(192) = −0·139	(221) = −0·144
(135) = −0·065	(164) = −0·308	(193) = −0·115	(222) = 0·798
(136) = −0·136	(165) = +0·128	(194) = +0·396	(223) = −0·827
(137) = −0·368	(166) = −0·628	(195) = +0·173	(224) = +0·300
(138) = −0·580	(167) = −0·098	(196) = 0·337	(225) = −0·080
(139) = −0·317	(168) = −0·854	(197) = 0·170	
(140) = −0·184	(169) = 0·092	(198) = −0·016	
(141) = −0·415	(170) = −0·085	(199) = −0·317	

(*d*) *Adjusted triangles, Kansas and Colorado.*

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
1	Lincoln	75	35	23·30	−0·87	24·17	0·54	4·499 [illegible]	31 [illegible]·71
	Thompson	58	20	09·09	−0·30	09·39	0·53	4·443 071 3	27 757 [illegible]
	Heath	46	04	25·23	−0·19	25·04	0·53	4·370 [illegible]	[illegible]
				0·62			1·60		
2	Golden Belt	47	33	59·22	0·77	59·45	0·72	4·499 [illegible]	31 [illegible] 71
	Thompson	33	54	02·43	−0·64	[illegible]	0·72	4·42[illegible]	[illegible]
	Heath	98	26	59·56	−1·07	60·63	0·71	4·629 734 6	42 [illegible]
				1·20			2·15		

(*d*) *Adjusted triangles, Kansas and Colorado*—Continued.

No.	Stations.	Observed angles. °	′	″	Correction. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
3	Golden Belt	68	30	27.01	+0.32	27.33	0.47	4.443 071 3	27 737.76
	Lincoln	64	07	02.24	−0.77	01.47	0.46	4.428 462 5	26 820.23
	Heath	47	22	31.33	+1.26	32.59	0.46	4.341 136 0	21 934.92
				0.58			1.39		
4	Lincoln	139	42	25.54	+0.10	25.64	0.29	4.629 734 6	42 631.89
	Thompson	19	26	06.66	−0.33	06.33	0.28	4.341 136 1	21 934.93
	Golden Belt	20	51	27.79	+1.09	28.88	0.28	4.370 548 1	23 471.89
				59.99			0.85		
5	Wilson	40	05	14.95	+0.24	15.19	0.87	4.443 071 4	27 737.76
	Lincoln	62	10	33.20	+0.95	34.15	0.87	4.580 857 6	38 094.09
	Heath	77	44	12.74	+0.54	13.28	0.88	4.624 191 9	42 091.26
				0.89			2.62		
6	Wilson	42	11	48.28	+1.15	49.43	0.44	4.428 462 6	26 820.24
	Golden Belt	107	26	31.10	+0.09	31.19	0.43	4.580 857 7	28 094.10
	Heath	30	21	41.41	−0.72	40.69	0.44	4.304 977 1	20 182.60
				0.79			1.31		
7	Golden Belt	175	56	58.11	+0.41	58.52	0.02	4.624 191 9	42 091.26
	Lincoln	1	56	29.04	−1.72	27.32	0.03	4.304 977 3	20 182.61
	Wilson	2	06	33.33	+0.91	34.24	0.03	4.341 136 0	21 934.92
				0.48			0.08		
8	Meades Ranch	62	23	31.27	+0.12	31.39	1.23	4.624 191 9	42 091.26
	Lincoln	57	53	15.30	−0.91	14.39	1.24	4.604 575 3	40 232.34
	Wilson	59	43	17.58	+0.35	17.93	1.24	4.612 995 3	41 019.96
				4.15			3.71		
9	Meades Ranch	23	36	44.70	+1.36	46.06	0.83	4.443 071 4	27 737.76
	Lincoln	120	03	48.50	+0.04	48.54	0.84	4.777 668 2	59 933.30
	Heath	36	19	28.42	−0.52	27.90	0.83	4.612 995 4	41 019.97
				1.62			2.50		
10	Wilson	99	48	32.53	+0.59	33.12	1.27	4.777 668 2	59 933.30
	Meades Ranch	38	46	46.57	−1.25	45.32	1.28	4.580 857 8	38 094.11
	Heath	41	24	44.32	+1.07	45.39	1.28	4.604 575 4	40 232.35
				3.42			3.83		
11	Golden Belt	91	44	41.12	−0.44	40.68	0.63	4.612 995 4	41 019.97
	Meades Ranch	32	18	35.07	−0.93	34.14	0.63	4.341 136 0	21 934.92
	Lincoln	55	56	46.26	+0.81	47.07	0.63	4.531 495 7	34 001.31
				2.45			1.89		

(*d*) *Adjusted triangles, Kansas and Colorado*—Continued.

No.	Stations.	Observed angles. °	′	″	Correction. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
12	Golden Belt	160	15	08 ·13	−0 ·12	08 ·01	0 ·26	4 ·777 668 2	59 933 ·30
	Meades Ranch	8	41	50 ·37	−2 ·30	48 ·07	0 ·26	4 ·428 462 7	26 820 ·24
	Heath	11	03	02 ·91	+1 ·79	04 ·70	0 ·26	4 ·531 496 0	34 001 ·34
				1 ·41			0 ·78		
13	Wilson	57	36	44 ·25	−0 ·56	43 ·69	0 ·58	4 ·531 495 9	34 001 ·33
	Meades Ranch	30	04	56 ·20	+1 ·05	57 ·25	0 ·58	4 ·304 977 3	20 182 ·61
	Golden Belt	92	18	20 ·77	+0 ·03	20 ·80	0 ·58	4 ·604 575 5	40 232 ·36
				1 ·22			1 ·74		
14	Bunker Hill	72	27	18 ·85	−0 ·75	18 ·10	0 ·64	4 ·604 575 4	40 232 ·35
	Meades Ranch	26	40	18 ·66	+0 ·32	18 ·98	0 ·64	4 ·277 392 9	18 940 ·56
	Wilson	80	52	25 ·31	−0 ·48	24 ·83	0 ·63	4 ·619 730 8	41 661 ·11
				2 ·82			1 ·91		
15	Waldo	62	59	56 ·22	+0 ·73	56 ·95	0 ·87	4 ·604 575 4	40 232 ·35
	Meades Ranch	82	10	52 ·87	−0 ·16	52 ·71	0 ·87	4 ·650 642 1	44 734 ·45
	Wilson	34	49	12 ·93	+0 ·02	12 ·95	0 ·87	4 ·411 335 2	25 783 ·11
				2 ·02			2 ·61		
16	Waldo	86	20	54 ·44	+0 ·06	54 ·50	0 ·75	4 ·619 730 8	41 661 ·11
	Meades Ranch	55	30	34 ·21	−0 ·48	33 ·73	0 ·75	4 ·536 654 9	34 407 ·64
	Bunker Hill	38	08	33 ·50	+0 ·52	34 ·02	0 ·75	4 ·411 335 2	25 783 ·11
				2 ·15			2 ·25		
17	Bunker Hill	110	35	52 ·35	−0 ·23	52 ·12	0 ·51	4 ·650 642 1	44 734 ·45
	Waldo	23	20	58 ·22	−0 ·67	57 ·55	0 ·52	4 ·277 392 9	18 940 ·56
	Wilson	46	03	12 ·38	−0 ·50	11 ·88	0 ·52	4 ·536 654 9	34 407 ·64
				2 ·95			1 ·55		
18	Blue Hill	60	58	19 ·81	+0 ·58	20 ·39	0 ·83	4 ·536 654 9	34 407 ·64
	Waldo	67	20	20 ·58	+0 ·19	20 ·77	0 ·83	4 ·560 060 3	36 312 ·85
	Bunker Hill	51	41	22 ·27	−0 ·94	21 ·33	0 ·83	4 ·489 633 1	30 876 ·86
				2 ·66			2 ·49		
19	Blue Hill	49	01	10 ·88	+0 ·42	11 ·30	1 ·28	4 ·619 730 8	41 661 ·11
	Meades Ranch	41	08	57 ·21	−0 ·02	57 ·19	1 ·28	4 ·560 060 4	36 312 ·86
	Bunker Hill	89	49	55 ·77	−0 ·42	55 ·35	1 ·28	4 ·741 821 0	55 185 ·00
				3 ·86			3 ·84		
20	Waldo	153	41	15 ·02	+0 ·25	15 ·27	0 ·30	4 ·741 821 0	55 185 ·00
	Meades Ranch	14	21	37 ·00	−0 ·46	36 ·54	0 ·30	4 ·489 633 2	30 876 ·87
	Blue Hill	11	57	08 ·93	+0 ·16	09 ·09	0 ·30	4 ·411 335 2	25 783 ·11
				0 ·95			0 90		

(*d*) *Adjusted triangles, Kansas and Colorado*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
21	Allen	65	34	08·54	−0·99	07·55	0·44	4·536 655 0	34 407·65
	Waldo	23	48	21·49	−1·51	19·98	0·44	4·183 381 0	15 253·90
	Bunker Hill	90	37	32·76	+1·04	33·80	0·45	4·577 369 5	37 789·36
				2·79			1·33		
22	Allen	54	04	59·09	+1·11	60·20	0·68	4·489 633 2	30 876·87
	Blue Hill	82	23	02·24	−1·19	01·05	0·68	4·577 369 3	37 789·34
	Waldo	43	31	59·09	+1·70	60·79	0·68	4·419 296 5	26 260·11
				0·42			2·04		
23	Allen	119	39	07·63	+0·11	07·74	0·30	4·560 060 4	36 312·86
	Blue Hill	21	24	42·43	−1·77	40·66	0·29	4·183 380 9	15 253·90
	Bunker Hill	38	56	10·49	+1·99	12·48	0·29	4·419 296 6	26 260·11
				0·55			0·88		
24	Fairmount	63	27	35·92	+1·03	36·95	0·90	4·560 060 4	36 312·86
	Blue Hill	56	38	05·94	−0·40	05·54	0·90	4·530 200 6	33 900·07
	Bunker Hill	59	54	20·96	−0·75	20·21	0·90	4·545 536 1	35 118·51
				2·82			2·70		
25	Fairmount	47	56	24·12	−0·91	23·21	0·45	4·419 296 5	26 260·11
	Blue Hill	35	13	23·51	+1·37	24·88	0·45	4·309 635 6	20 400·25
	Allen	96	50	12·45	+0·81	13·26	0·45	4·545 536 1	35 118·51
				0·08			1·35		
26	Allen	143	30	39·92	−0·92	39·00	0·15	4·530 200 6	33 900·07
	Bunker Hill	20	58	10·47	−2·74	07·73	0·16	4·309 635 5	20 400·25
	Fairmount	15	31	11·80	+1·94	13·74	0·16	4·183 380 5	15 253·89
				2·19			0·47		
27	Hays	75	48	30·94	+1·48	32·42	0·48	4·545 536 1	35 118·51
	Blue Hill	76	42	44·95	+0·05	45·00	0·49	4·547 210 6	35 254·18
	Fairmount	27	28	43·65	+0·38	44·03	0·48	4·223 092 1	16 714·45
				59·54			1·45		
28	Hays	42	33	46·60	+0·72	47·32	0·34	4·419 296 5	26 260·11
	Blue Hill	111	56	08·46	+1·42	09·88	0·35	4·556 453 8	36 012·55
	Allen	25	30	04·14	−0·31	03·83	0·34	4·223 092 0	16 714·45
				59·20			1·03		
29	Fairmount	75	25	07·77	−0·53	07·24	0·59	4·556 453 9	36 012·55
	Hays	33	14	44·34	+0·76	45·10	0·59	4·309 635 6	20 400·25
	Allen	71	20	08·31	+1·12	09·43	0·59	4·547 210 7	35 254·18
				0·42			1·77		

(*d*) *Adjusted triangles, Kansas and Colorado*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
30	La Crosse	68	50	05·03	−0·77	04·26	0·70	4·547 210 7	35 254·18
	Hays	40	54	41·48	−1·60	39·88	0·70	4·393 707 7	24 757·55
	Fairmount	70	15	17·80	+0·15	17·95	0·69	4·551 227 0	35 581·72
				4·31			2·09		
31	La Crosse	49	43	40·29	−1·73	38·56	0·73	4·545 536 2	35 118·52
	Blue Hill	32	32	20·51	+1·14	21·65	0·73	4·393 707 8	24 757·56
	Fairmount	97	44	01·45	+0·53	01·98	0·73	4·659 057 6	45 609·74
				2·25			2·19		
32	Hays	116	43	12·42	−0·11	12·31	0·45	4·659 057 6	45 609·74
	Blue Hill	44	10	24·44	−1·09	23·35	0·45	4·551 227 0	35 581·72
	La Crosse	19	06	24·74	+0·95	25·69	0·45	4·223 092 2	16 714·45
				1·60			1·35		
33	Smoky Hill	72	10	40·40	+0·18	40·58	0·72	4·551 227 0	35 581·72
	Hays	49	23	59·05	+0·40	59·45	0·73	4·452 979 9	28 377·88
	La Crosse	58	25	21·14	+1·01	22·15	0·73	4·502 991 0	31 841·32
				0·59			2·18		
34	Smoky Hill	47	44	26·78	+1·19	27·97	0·95	4·547 210 7	35 254·18
	Hays	90	18	40·53	−1·19	39·43	0·95	4·677 907 7	47 632·98
	Fairmount	41	56	56·84	−1·30	55·54	0·95	4·502 991 0	31 841·32
				4·15			2·85		
35	Smoky Hill	24	26	13·62	−1·00	12·62	0·47	4·393 707 7	24 757·55
	Fairmount	28	18	20·96	+1·44	22·40	0·47	4·452 979 8	28 377·87
	La Crosse	127	15	26·17	+0·23	26·40	0·48	4·677 907 5	47 632·96
				0·75			1·42		
36	Trego	71	05	55·74	+0·02	55·76	0·52	4·502 991 0	31 841·32
	Hays	37	51	04·08	+0·72	04·80	0·53	4·314 958 5	20 651·83
	Smoky Hill	71	03	01·50	−0·48	01·02	0·53	4·502 864 9	31 832·07
				1·32			1·48		
37	Skaggs	46	13	44·62	−0·48	44·14	0·34	4·314 958 6	20 651·83
	Trego	42	53	33·58	+0·28	33·86	0·34	4·289 265 1	19 465·48
	Smoky Hill	90	52	42·85	+0·17	43·02	0·34	4·456 305 0	28 595·98
				1·05			1·02		
38	Skaggs	32	29	16·58	+0·40	16·98	0·38	4·452 980 0	28 377·88
	Smoky Hill	125	53	35·25	+0·14	35·39	0·38	4·631 452 4	42 800·85
	La Crosse	21	37	09·56	−0·79	08·77	0·38	4·289 265 3	19 465·49
				1·39			1·14		

(*d*) *Adjusted triangles, Kansas and Colorado*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
39	Big Creek	58	23	56·89	−0·52	56·37	0·55	4·456 305 0	28 595·98
	Trego	77	09	51·60	−0·08	51·52	0·56	4·515 019 4	32 735·53
	Skaggs	44	26	13·31	+0·46	13·77	0·35	4·371 185 4	23 506·36
				1·80			1·66		
40	Schmidt	41	07	11·57	+1·35	12·92	0·63	4·456 305 0	28 595·98
	Trego	37	33	32·55	+0·09	32·64	0·63	4·423 345 6	26 506·09
	Skaggs	101	19	15·59	+0·74	16·33	0·63	4·629 783 8	42 636·72
				59·71			1·89		
41	Schmidt	72	32	40·92	+0·39	41·31	0·61	4·515 019 4	32 735·53
	Big Creek	50	34	17·74	+0·23	17·97	0·62	4·423 345 4	26 506·07
	Skaggs	56	53	02·28	+0·29	02·57	0·62	4·458 511 8	28 741·66
				0·94			1·85		
42	Big Creek	108	58	14·63	−0·29	14·34	0·54	4·629 783 8	42 636·72
	Trego	39	36	19·05	−0·17	18·88	0·54	4·458 511 9	28 741·66
	Schmidt	31	25	29·35	−0·95	28·40	0·54	4·371 185 4	23 506·36
				3·03			1·62		
43	Indian Creek	35	11	52·21	−0·07	52·14	1·00	4·458 511 8	28 741·66
	Big Creek	55	44	14·35	- 0·48	13·87	1·00	4·615 012 3	41 210·92
	Schmidt	89	03	56·94	+0·05	56·99	1·00	4·697 732 1	49 857·68
				3·50			3·00		
44	Canyon	25	39	29·16	−0·68	28·48	0·68	4·458 511 8	28 741·66
	Big Creek	30	23	31·47	+0·57	32·04	0·68	4·526 106 5	33 581·99
	Schmidt	123	57	01·53	−0·02	01·51	0·67	4·740 858 2	55 062·79
				2·16			2·03		
45	Canyon	90	32	38·69	−0·96	37·73	0·67	4·615 012 4	41 210·93
	Indian Creek	54	34	20·47	−0·71	19·76	0·67	4·526 106 5	33 581·99
	Schmidt	34	53	04·59	−0·07	04·52	0·67	4·372 369 1	23 570·52
				3·75			2·01		
46	Indian Creek	89	46	12·68	−0·78	11·90	1·00	4·740 858 3	55 062·80
	Big Creek	25	20	42·88	−1·05	41·83	0·99	4·372 369 2	23 570·52
	Canyon	64	53	09·53	−0·28	09·25	0·99	4·697 732 2	49 857·69
				5·09			2·98		
47	Beaver	36	36	58·15	−0·37	57·78	0·71	4·372 369 1	23 570·52
	Indian Creek	72	53	34·93	+0·38	35·31	0·71	4·577 144 7	37 769·80
	Canyon	70	29	29·01	+0·03	29·04	0·71	4·571 120 2	37 249·48
				2·09			2·13		

(*d*) *Adjusted triangles, Kansas and Colorado*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
48	Monument	28	57	04·75	−0·35	04·40	0·69	4·372 369 1	23 570·52
	Indian Creek	103	56	06·94	+0·24	07·18	0·69	4·674 494 6	47 260·10
	Canyon	47	06	49·97	+0·52	50·49	0·69	4·552 398 7	35 677·85
				1·66			2·07		
49	Monument	78	54	59·15	−0·25	58·90	0·58	4·571 120 2	37 249·48
	Indian Creek	31	02	32·01	−0·14	31·87	0·58	4·291 666 6	19 573·42
	Beaver	70	02	31·03	−0·06	30·97	0·58	4·552 398 5	35 677·83
				2·19			1·74		
50	Beaver	106	39	29·18	−0·43	28·75	0·60	4·674 494 6	47 260·10
	Monument	49	57	54·40	+0·09	54·49	0·60	4·577 144 7	37 769·80
	Canyon	23	22	39·04	−0·48	38·56	0·60	4·291 666 6	19 573·42
				2·62			1·80		
51	Gopher	25	54	21·61	−0·68	20·93	0·37	4·291 666 6	19 573·42
	Monument	118	55	14·21	−0·14	14·07	0·38	4·593 446 0	39 214·44
	Beaver	35	10	25·94	+0·18	26·12	0·37	4·411 760 0	25 808·33
				1·76			1·12		
52	Sheridan	25	36	25·25	−0·78	24·47	0·68	4·291 666 6	19 573·42
	Monument	89	31	03·05	−0·79	02·26	0·68	4·655 976 6	45 287·32
	Beaver	64	52	35·94	−0·63	35·31	0·68	4·612 829 3	41 004·29
				4·24			2·04		
53	Sheridan	59	59	05·77	−0·84	04·93	0·75	4·593 446 1	39 214·45
	Gopher	90	18	47·78	+0·34	48·12	0·74	4·655 976 8	45 287·34
	Beaver	29	42	10·00	−0·81	09·19	0·75	4·351 021 8	22 439·94
				3·55			2·24		
54	Gopher	116	13	09·39	−0·34	09·05	0·44	4·612 829 4	41 004·30
	Monument	29	24	11·16	+0·65	11·81	0·44	4·351 021 8	22 439·94
	Sheridan	34	22	40·52	−0·06	40·46	0·44	4·411 760 1	25 808·34
				1·07			1·32		
55	Teeters Hill	47	45	11·45	−0·27	11·18	0·47	4·351 021 8	22 439·94
	Gopher	58	58	44·98	+0·20	45·18	0·47	4·414 611 9	25 978·37
	Sheridan	73	16	04·42	+0·64	05·06	0·48	4·462 853 6	29 030·44
				0·85			1·42		
56	Wallace Bluffs	19	55	44·35	−0·07	44·28	0·23	4·351 021 8	22 439·94
	Gopher	17	31	13·94	−0·61	13·33	0·23	4·297 083 3	19 819·07
	Sheridan	142	33	02·74	+0·34	03·08	0·23	4·602 398 6	40 031·20
				1·03			0·69		

(*d*) *Adjusted triangles, Kansas and Colorado*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
57	Wallace Bluffs	66	22	26·11	−0·20	25·91	0·41	4·414 611 9	25 978·37
	Teeters Hill	44	20	36·59	+0·70	37·29	0·41	4·297 083 4	19 819·08
	Sheridan	69	16	58·32	−0·30	58·02	0·40	4·423 599 6	26 521·59
				1·02			1·22		
58	Teeters Hill	92	05	48·04	+0·43	48·47	0·65	4·602 398 6	40 031·20
	Gopher	41	27	31·04	+0·81	31·85	0·65	4·423 599 6	26 521·59
	Wallace Bluffs	46	26	41·76	−0·13	46·63	0·65	4·462 853 6	29 030·44
				0·84			1·95		
59	Turtle	64	58	29·58	−0·69	28·89	0·46	4·423 599 6	26 521·59
	Teeters Hill	56	32	52·79	−1·05	51·74	0·47	4·387 758 9	24 420·75
	Wallace Bluffs	58	28	41·04	−0·27	40·77	0·47	4·397 076 7	24 950·35
				3·41			1·40		
60	Turtle	40	30	34·56	+0·21	34·77	0·54	4·414 611 9	25 978·37
	Teeters Hill	100	53	29·38	−0·36	29·02	0·53	4·594 089 1	39 272·55
	Sheridan	38	35	58·62	−0·80	57·82	0·54	4·397 076 7	24 950·35
				2·56			1·61		
61	Turtle	24	27	55·02	−0·89	54·13	0·34	4·297 083 5	19 819·08
	Sheridan	30	40	59·70	+0·50	60·20	0·34	4·387 759 1	24 420·76
	Wallace Bluffs	124	51	07·15	−0·47	06·68	0·33	4·594 089 3	39 272·57
				1·87			1·01		
62	Curlew	80	38	40·29	+0·03	40·32	0·29	4·387 759 0	24 420·75
	Turtle	44	34	33·15	+0·13	33·28	0·29	4·239 820 4	17 370·82
	Wallace Bluffs	54	46	46·88	+0·39	47·27	0·29	4·305 765 1	20 219·25
				0·32			0·87		
63	Curlew	39	27	16·31	−0·32	15·99	0·40	4·397 076 8	24 950·36
	Turtle	109	33	02·73	−0·55	02·18	0·41	4·568 197 5	36 999·64
	Teeters Hill	30	59	44·10	−1·06	43·04	0·40	4·305 765 1	20 219·25
				3·14			1·21		
64	Curlew	41	11	23·98	+0·36	24·34	0·36	4·423 599 7	26 521·60
	Teeters Hill	25	33	08·69	+0·01	08·70	0·36	4·239 820 4	17 370·82
	Wallace Bluffs	113	15	27·92	+0·11	28·03	0·35	4·568 197 4	36 999·63
				0·59			1·07		
65	McLane	49	53	11·63	−0·40	11·23	0·31	4·305 765 1	20 219·25
	Turtle	87	26	09·74	+0·15	09·89	0·30	4·421 800 4	26 411·95
	Curlew	42	40	39·88	−0·08	39·80	0·31	4·253 383 5	17 921·88
				1·25			0·92		

(*d*) *Adjusted triangles, Kansas and Colorado*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
66	McLane	27	54	09·28	−1·14	08·14	0·28	4·387 759 0	24 420·75
	Turtle	132	00	42·89	+0·29	43·18	0·27	4·588 539 1	38 773·86
	Wallace Bluffs	20	05	09·04	+0·47	09·51	0·28	4·253 383 4	17 921·87
				1·21			0·83		
67	McLane	21	59	02·35	+0·74	03·09	0·32	4·239 820 4	17 370·82
	Wallace Bluffs	34	41	37·84	−0·08	37·76	0·32	4·421 800 2	26 411·93
	Curlew	123	19	20·17	−0·05	20·12	0·33	4·588 539 1	38 773·86
				0·36			0·97		
68	Arapahoe	51	58	53·72	+0·16	53·88	0·60	4·421 800 3	26 411·94
	McLane	57	53	13·35	−0·16	13·19	0·60	4·453 261 2	28 396·26
	Curlew	70	07	54·18	+0·54	54·72	0·59	4·498 725 7	31 530·13
				1·25			1·79		
69	Arapahoe	24	45	....	....	41·30	0·46	4·253 383 6	17 921·88
	McLane	107	46	24·98	−0·56	24·42	0·45	4·610 096 8	40 747·11
	Turtle	47	27	55·27	+0·38	55·65	0·46	4·498 725 9	31 530·14
							1·37		
70	Arapahoe	27	13	....	....	12·59	0·45	4·305 765 2	20 219·26
	Turtle	39	58	14·47	−0·23	14·24	0·45	4·453 261 3	28 396·27
	Curlew	112	48	34·06	+0·45	34·51	0·44	4·610 096 8	40 747·11
							1·34		
71	Monotony	66	02	45·24	+0·34	45·58	0·61	4·498 725 8	31 530·13
	McLane	68	05	44·09	+0·54	44·63	0·62	4·505 298 9	32 010·98
	Arapahoe	45	51	31·15	+0·48	31·63	0·61	4·393 737 7	24 759·26
				0·48			1·84		
72	Monotony	27	57	07·25	−0·20	07·05	0·45	4·421 800 4	26 411·95
	McLane	125	58	57·44	+0·38	57·82	0·44	4·658 931 9	45 596·54
	Curlew	26	03	56·73	−0·26	56·47	0·45	4·393 737 9	24 759·27
				1·42			1·34		
73	Monotony	38	05	37·99	+0·54	38·53	0·76	4·453 261 3	28 396·27
	Curlew	44	03	57·45	+0·79	58·24	0·76	4·505 299 0	32 010·99
	Arapahoe	97	50	24·87	+0·65	25·52	0·77	4·658 931 9	45 596·54
				0·31			2·29		
74	Cheyenne Wells	71	09	20·61	+0·50	21·11	0·42	4·505 298 9	32 010·98
	Monotony	81	13	03·41	−0·47	02·94	0·42	4·524 101 8	33 427·34
	Arapahoe	27	37	37·04	+0·17	37·21	0·42	4·195 472 3	15 684·56
				1·06			1·26		

(*d*) *Adjusted triangles, Kansas and Colorado*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
75	First View	49	30	34 ·10	+0 ·07	34 ·17	0 ·93	4 ·505 298 9	32 010 ·98
	Monotony	69	48	12 ·86	+0 ·79	13 ·65	0 ·94	4 ·596 634 5	39 503 ·40
	Arapahoe	60	41	14 ·89	+0 ·09	14 ·98	0 ·93	4 ·564 690 3	36 702 ·05
				1 ·85			2 ·80		
76	First View	57	47	22 ·43	+0 ·47	22 ·90	0 ·61	4 ·524 101 8	33 427 ·34
	Cheyenne Wells	89	09	01 ·68	−0 ·53	01 ·15	0 ·61	4 ·596 634 5	39 503 ·40
	Arapahoe	33	03	37 ·85	−0 ·07	37 ·78	0 ·61	4 ·333 494 4	21 552 ·34
				1 ·96			1 ·83		
77	Cheyenne Wells	160	18	22 ·29	−0 ·03	22 ·26	0 ·09	4 ·564 690 4	36 702 ·06
	Monotony	11	24	50 ·55	−1 ·26	49 ·29	0 ·10	4 ·333 494 5	21 552 ·34
	First View	8	16	48 ·33	+0 ·41	48 ·74	0 ·10	4 ·195 472 4	15 684 ·56
				1 ·17			0 ·29		
78	Landsman	95	57	59 ·19	−0 ·26	58 ·93	0 ·44	4 ·564 690 4	36 702 ·06
	Monotony	27	55	21 ·13	−0 ·53	20 ·60	0 ·45	4 ·237 548 6	17 280 ·19
	First View	56	06	42 ·59	−0 ·78	41 ·81	0 ·45	4 ·486 192 3	30 633 ·20
				2 ·91			1 ·34		
79	Landsman	15	56	56 ·56	+1 ·14	57 ·70	0 ·12	4 ·195 472 4	15 684 ·56
	Monotony	16	30	30 ·58	+0 ·73	31 ·31	0 ·12	4 ·210 039 5	16 219 ·58
	Cheyenne Wells	147	32	30 ·36	+0 ·98	31 ·34	0 ·11	4 ·486 192 3	30 633 ·20
				57 ·50			0 ·35		
80	Landsman	80	01	02 ·63	−1 ·41	01 ·22	0 ·24	4 ·333 494 5	21 552 ·34
	Cheyenne Wells	52	09	07 ·35	−0 ·95	06 ·40	0 ·23	4 ·237 548 6	17 280 ·19
	First View	47	49	54 ·26	−1 ·18	53 ·08	0 ·23	4 ·210 039 4	16 219 ·57
				4 ·24			0 ·70		
81	Kit Carson	28	09	43 ·09	+0 ·26	43 ·35	0 ·42	4 ·237 548 6	17 280 ·19
	Landsman	52	14	40 ·75	+0 ·25	41 ·00	0 ·42	4 ·461 613 1	28 947 ·63
	First View	99	35	36 ·14	+0 ·76	36 ·90	0 ·41	4 ·557 522 3	36 101 ·26
				59 ·98			1 ·25		
82	Eureka	28	42	22 ·15	−0 ·75	21 ·40	0 ·33	4 ·237 548 6	17 280 ·19
	Landsman	109	15	39 ·62	+0 ·59	40 ·21	0 ·34	4 ·531 007 8	33 963 ·14
	First View	42	01	58 ·81	+0 ·58	59 ·39	0 ·33	4 ·381 813 3	24 088 ·70
				0 ·58			1 ·00		
83	Eureka	81	40	04 ·74	−0 ·02	04 ·72	0 ·61	4 ·557 522 3	36 101 ·26
	Landsman	57	00	58 ·87	+0 ·33	59 ·20	0 ·62	4 ·485 802 3	30 605 ·70
	Kit Carson	41	18	57 ·91	+0 ·02	57 ·93	0 ·62	4 ·381 813 1	24 088 ·69
				1 ·52			1 ·85		

(*d*) *Adjusted triangles, Kansas and Colorado*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
84	Kit Carson	69	28	41·00	+0·28	41·28	0·71	4·531 007 8	33 963·14
	Eureka	52	57	42·59	+0·73	43·32	0·70	4·461 613 2	28 947·64
	First View	57	33	37·33	+0·18	37·51	0·70	4·485 802 4	30 605·71
				0·92			2·11		
85	Aroya	56	46	54·05	+0·51	54·56	0·72	4·485 802 4	30 605·71
	Eureka	55	33	13·81	+0·02	13·83	0·72	4·479 563 3	40 169·16
	Kit Carson	67	39	53·28	+0·50	53·78	0·73	4·529 420 9	33 839·26
				1·14			2·17		
86	Overland	39	53	01·47	−0·51	00·96	0·69	4·485 802 4	30 605·71
	Eureka	104	51	57·46	−0·38	57·08	0·69	4·664 005 6	46 132·35
	Kit Carson	35	15	04·73	−0·70	04·03	0·69	4·440 085 4	27 547·70
				3·66			2·07		
87	Overland	77	55	51·62	−0·34	51·28	0·59	4·529 420 9	33 839·26
	Eureka	49	18	43·65	−0·41	43·24	0·60	4·418 951 8	26 239·27
	Aroya	52	45	27·52	−0·25	27·27	0·60	4·440 085 3	27 547·70
				2·79			1·79		
88	Aroya	109	32	21·57	+0·26	21·83	0·63	4·664 005 6	46 132·35
	Overland	38	02	50·15	+0·17	50·32	0·63	4·479 563 3	30 169·16
	Kit Carson	32	24	48·55	+1·19	49·74	0·63	4·418 951 7	26 239·27
				0·27			1·89		
89	Hugo	38	40	10·24	+0·76	11·00	0·66	4·418 951 8	26 239·27
	Overland	95	51	44·77	+0·49	45·26	0·66	4·620 914 3	41 774·79
	Aroya	45	28	04·76	+0·96	05·72	0·66	4·476 195 7	29 936·13
				59·77			1·98		
90	Adobe	27	07	36·67	−0·21	36·46	0·71	4·418 951 8	26 239·27
	Overland	37	44	01·15	+0·19	01·34	0·71	4·546 771 0	35 218·51
	Aroya	115	08	24·58	−0·26	24·32	0·70	4·716 806 6	52 096·27
				2·40			2·12		
91	Adobe	62	08	25·89	−0·21	25·68	1·17	4·620 914 3	41 774·79
	Hugo	48	11	20·08	−0·87	19·21	1·17	4·546 770 8	35 218·50
	Aroya	69	40	19·82	−1·21	18·61	1·16	4·646 487 7	44 308·57
				5·79			3·50		
92	Hugo	86	51	30·32	−0·10	30·22	1·12	4·716 8[illegible]	52 096·27
	Overland	58	07	43·62	+0·30	43·92	1·12	4·646 487 8	44 308·58
	Adobe	35	00	49·22	0·00	49·22	1·12	4·476 195 8	29 936·14
				3·16			3·36		

(*d*) *Adjusted triangles, Kansas and Colorado*—Completed.

No	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
93	Square Bluffs	81	20	08·97	−2·16	06·81	0·94	4·646 487 8	44 308·58
	Hugo	43	14	05·08	−0·14	04·94	0·95	4·487 154 4	30 701·13
	Adobe	55	25	52·71	−1·62	51·09	0·95	4·567 105 0	36 906·68
				6·76			2·84		
94	Holt	65	09	15·46	+0·90	16·36	0·74	4·567 105 0	36 906·68
	Hugo	36	25	45·18	+0·56	45·74	0·74	4·382 946 7	24 151·64
	Square Bluffs	78	24	58·73	+1·39	60·12	0·74	4·600 349 1	39 842·73
				59·37			2·22		
95	Holcolm Hills	29	14	12·26	+1·63	13·89	0·57	4·382 946 7	24 151·64
	Holt	113	09	57·99	+0·19	58·18	0·56	4·657 639 7	45 461·08
	Square Bluffs	37	35	49·86	−0·23	49·63	0·57	4·479 553 1	30 168·46
				0·11			1·70		
96	Cramers Gulch	56	38	46·63	−0·04	46·59	0·73	4·487 154 4	30 701·13
	Square Bluffs	68	21	10·85	+1·15	12·00	0·72	4·533 554 8	34 162·90
	Adobe	55	00	01·53	+2·06	03·59	0·73	4·478 685 7	30 108·26
				59·01			2·18		
97	Big Springs	49	05	18·62	−0·39	18·23	0·81	4·478 685 7	30 108·26
	Square Bluffs	55	56	17·88	−0·23	17·65	0·81	4·518 582 7	33 005·23
	Cramers Gulch	74	58	26·04	+0·52	26·56	0·82	4·585 216 4	38 478·35
				2·54			2·44		
98	Holcolm Hills	57	22	15·17	−0·83	14·34	0·92	4·585 216 4	38 478·35
	Square Bluffs	38	21	33·71	+0·09	33·80	0·92	4·452 618 5	28 354·27
	Big Springs	84	16	14·31	+0·31	14·62	0·92	4·657 639 6	45 461·07
				3·19			2·76		

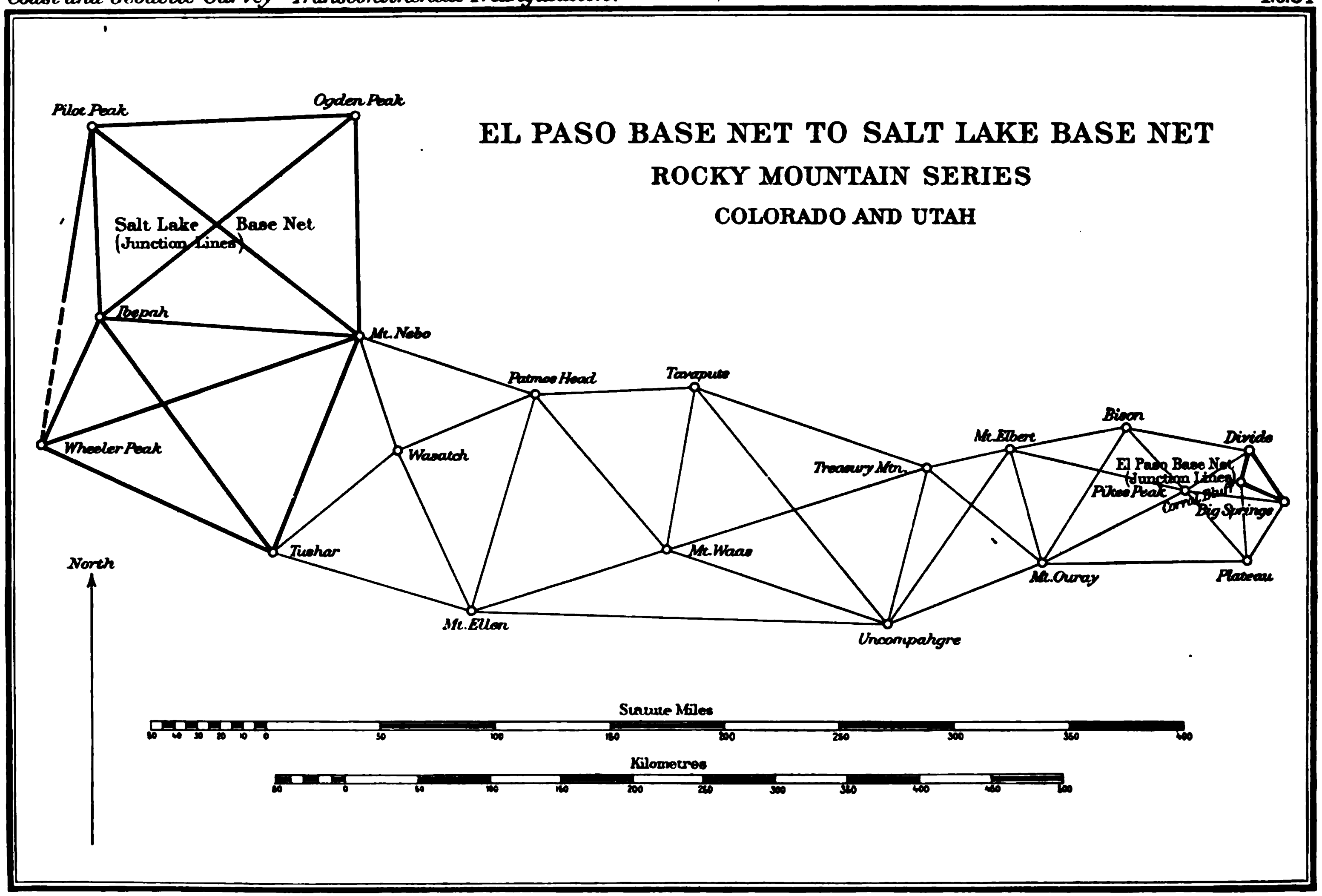
(*e*) *The precision of the adjusted triangulation.*

To get a close estimate of the precision of this triangulation, we determine first the mean error of an angle resulting from the adjustment. We have $m = \sqrt{\frac{2[pvv]}{c}}$. In this case $p = 1$, $c = 99$, and $[vv] = 53·93$. Hence $m = \pm 1''·04$.

The probable error in length of any line of the series due to the angular measures is found by the usual formulæ—

$$u_{a_n} = \frac{2}{3}(\delta_{a_n})^2 \sum_{a_1}^{a_n}[\delta_A^2 + \delta_A\delta_B + \delta_B^2] \quad \text{and} \quad e_{a_n} = 0·674\,5\ m\sqrt{u_{a_n}}$$

We will divide the series into four parts by the lines Hays-La Crosse, Monument-Beaver, and Landsman-First View, and compute the probable error in length of each of these lines.


EL PASO BASE NET TO SALT LAKE BASE NET
ROCKY MOUNTAIN SERIES
COLORADO AND UTAH
Pilot Peak
Ogden Peak
Salt Lake Base Net
(Junction Lines)
Ibapah
Mt. Nebo
Wheeler Peak
Wasatch
Tushar
Patmos Head
Tavaputs
Mt. Ellen
Mt. Waas
Treasury Mtn.
Uncompahgre
Mt. Elbert
Bison
Mt. Ouray
Divide
El Paso Base Net
(Junction Lines)
Pikes Peak
Big Springs
Plateau
North
Statute Miles
Kilometres

For the first, starting from the side Thompson-Heath of the Salina Base figure, we have $\delta_{a_n} = 12{\cdot}2$, $\Sigma = 26{\cdot}9$ (9 triangles), $e_{a_n} = \pm 0{\cdot}244$ metre, $e_b = \pm 0{\cdot}181$ metre, and $e_1 = \pm 0{\cdot}304$ metre.

Starting from the side Holcolm Hills-Big Springs of the El Paso Base figure, $\Sigma = 219{\cdot}5$ (30 triangles), $e_{a_n} = \pm 0{\cdot}698$ metre, $e_b = \pm 0{\cdot}102$ metre, and $e_2 = \pm 0{\cdot}705$ metre.

$e = \dfrac{e_1 e_2}{\sqrt{e_1^2 + e_2^2}} = \pm 0{\cdot}279$ metre, which is about $\frac{1}{188000}$ part of the length.

For the side Monument-Beaver $\delta_{a_n} = 22{\cdot}2$. Starting from the side Thompson-Heath, $\Sigma = 98{\cdot}4$ (18 triangles), $e_{a_n} = \pm 0{\cdot}257$ metre, $e_b = \pm 0{\cdot}099$ metre, and $e_1 = \pm 0{\cdot}275$ metre.

Starting from the other end $\Sigma = 148{\cdot}0$ (21 triangles), $e_{a_n} = \pm 0{\cdot}3150$ metre, $e_b = \pm 0{\cdot}056$ metre, and $e_2 = \pm 0{\cdot}320$ metre. Hence $e = \pm 0{\cdot}209$ metre, or about $\frac{1}{94000}$ part of the length.

For the side Landsman-First View, starting from Thompson-Heath $\delta_{a_n} = 25{\cdot}2$, $\Sigma = 183{\cdot}8$ (29 triangles), $e_{a_n} = \pm 0{\cdot}309$ metre, $e_b = \pm 0{\cdot}088$ metre, and $e_1 = \pm 0{\cdot}321$ metre.

Starting from the line Holcolm Hills-Big Springs, $\Sigma = 62{\cdot}6$ (10 triangles), $e_{a_n} = \pm 0{\cdot}180$ metre, $e_b = \pm 0{\cdot}050$ metre, and $e_2 = \pm 0{\cdot}187$ metre. Hence $e = \pm 0{\cdot}161$ metre, or about $\frac{1}{107000}$ part of the length.

For the effect on the developed length of the arc, we have approximately, the distances being taken between the middle points of the terminal lines projected on the thirty-ninth parallel—

Terminal lines.	Distance.	Probable errors.		Average.	
	km.				*m.*
Thompson and Heath to Hays and La Crosse	115·5	$\frac{1}{157000}$	$\frac{1}{128000}$	$\frac{1}{153000}$	±0·75
Hays and La Crosse to Monument and Beaver	139·0	$\frac{1}{128000}$	$\frac{1}{94000}$	$\frac{1}{108000}$	1·29
Monument and Beaver to Landsman and First View	147·0	$\frac{1}{91000}$	$\frac{1}{107000}$	$\frac{1}{100000}$	1·47
Landsman and First View to Holcolm Hills and Big Springs	148·7	$\frac{1}{107000}$	$\frac{1}{350000}$	$\frac{1}{161000}$	0·91
	550·2				±4·42

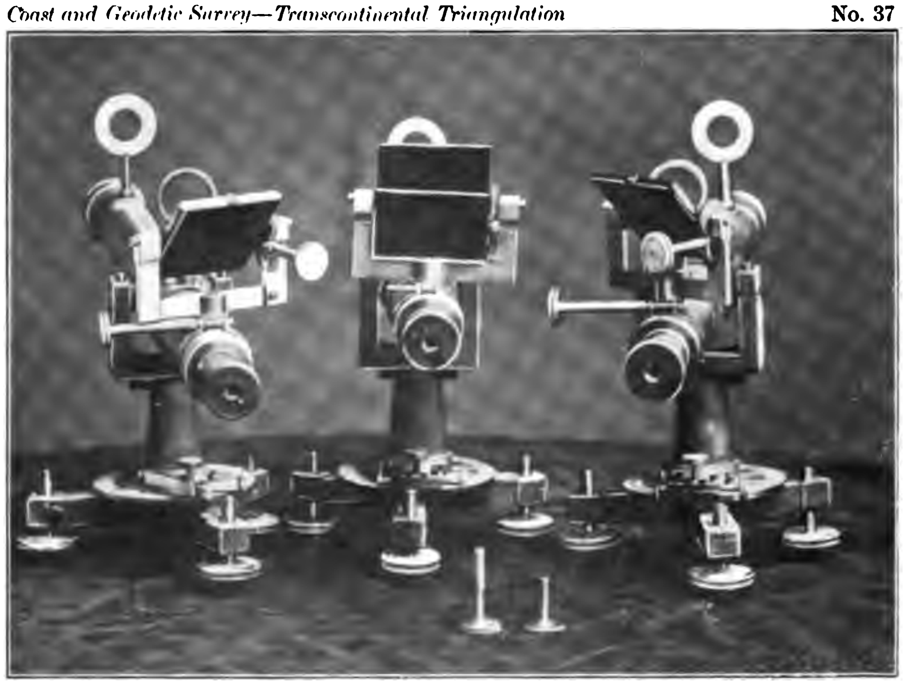
9. THE ROCKY MOUNTAIN SERIES OF TRIANGLES, 1885, 1890–91, 1893–94–95.

(*a*) *Introduction.*

It may be said that upon the whole but few obstacles were encountered in the execution of the triangulation between the Atlantic and the foot of the Rocky Mountains, and these were mainly the presence of lofty forests or of parallel ridges of nearly equal altitude. Facilities of transportation and of living were sufficiently abundant in this region, except perhaps in that part of the triangulation which crosses the Allegheny Mountains. For the remaining third of the way across the continent the character of the work is totally different, on account of the high altitudes of the stations, the sparse population, and the deficiency of roads, as may be seen from the following information and description furnished by the observer, Assistant W. Eimbeck.

With but few exceptions the belt of country between Pikes Peak and Salt Lake traversed by the main triangulation is characterized by stupendous masses of mountains with intricate summit topography. The continental divide in western Colorado, for example, rises as a strongly serrated wall with innumerable defiant peaks. Though rugged and often difficult of access, the mountains along the thirty-ninth parallel are nevertheless a favorable feature, inasmuch as they admit of a triangulation on a comprehensive and unusually grand scale; on the other hand, the crossing of the extensive table mountains in eastern Utah necessitated a contracted central figure of the triangulation. The stations comprised within this section rise to an average elevation of about 3 650 metres (12 000 feet), and the crossing of the continental divide was effected by the occupation of five peaks, reaching an average elevation of nearly 4 300 metres (14 100 feet). We have here the longest side of the triangulation, viz: 294 kilometres or 182·7 statute miles. As a rule the country traversed is an arid, barren waste, with but a few settlements along the main rivers; within the timber belt, between the 7 000 and 11 000 foot level, there is abundance of water. The principal drawback to the prosecution of the work was the almost total absence of modern ways of transportation, ordinary freight wagons and pack animals being the only means available. The Denver and Rio Grande Railway with its Ogden branch however afforded much relief. The wagon roads had frequently to be made passable by building bridges across gulleys. Lower camps were established at the end of transportation by wagon, and a pack trail was located and opened to the upper camp, usually distant 5 to 10 miles, and involving much cutting of fallen timber, grading, and blasting or quarrying of rocks; the ascent was usually between 3 000 and 7 000 feet. Ordinarily about 10 000 pounds (say, 5 000 kilogrammes) of outfit, instruments, and provisions had to be transported to the upper camp—usually two weeks' labor—for which purpose from 5 to 7 pack mules were employed, each carrying as a load about 150 pounds—rarely and exceptionally as much as 200 pounds—according to length of trail, steepness, and height of ascent. The transportation of the great theodolite, weighing with packing box about 200 pounds, required from one to two days. Sometimes it was carried by hand; at other times it was drawn by a horse and guided by men. This was accomplished by men carrying and guiding it while a horse was pulling it by means of a rope. The preparatory work to put the mountain top in condition for occupation was usually very considerable. The instruments were mounted on masonry or rock, the observer stood upon a raised floor, and the whole was walled in and surmounted by a stout canvas tent in order to break the force of the wind. The theodolite stood upon its iron position stand, and was effectively protected against direct sunlight and radiant heat by the double-walled and double-roofed observing tent. As the occupation of a station covered about one month, only two principal stations a year could be disposed of, since the favorable season lasted but four months. The reconnaissance was made by Assistant Eimbeck *pari passu* with the occupation of the station. The party of occupation was composed of three officers and a recorder, with the necessary complement of men acting as packers, drivers, and cooks, the whole party consisting of 12 or 13 persons. The heliotropers stationed in pairs at the distant stations numbered from 10 to 20, according to the requirements of the figure of the triangulation. In consequence of their long connection with the work, these heliotropers had acquired the needful training and familiarity with their duties; they lived in tents or stone cabins or "dugouts," close to their stations, and considering the exposure and isolation of their positions it must be conceded that they acquitted themselves well of their trying and responsible duty. With

VIEW OF CIMARRON CANYON, AS SEEN FROM UNCOMPAHGRE PEAK.



HELIOTROPES OF LATEST PATTERN.

THE 50-CM. OR 20-INCH THEODOLITE, USED AT THE PRIMARY STATIONS IN THE ROCKY MOUNTAIN REGION.

INTERIOR STATION ON OGDEN PEAK, SHOWING MOUNTING OF INSTRUMENT ON POSITION STAND.

Altitude 2,924 meters or 10,592 feet

SUMMIT STATION ON TREASURY PEAK, LOOKING EAST, SHOWING PERFORATIONS OF WALL TENT FOR OBSERVATION WITH LARGE THEODOLITE.

Altitude, 4,098 meters or 13,444 feet.

HIGH SUMMIT STATION, TUSHAR MOUNTAIN, UTAH, SHOWING RING WALL AND DOUBLE SHELTER TENT AGAINST STORMS AND RADIATION OF HEAT.

Altitude, 3,702 meters or 12,146 feet.

but few exceptions the horizontal directions and zenith distances were observed upon heliotrope light. As a rule the reflectors were of square shape, varying in dimensions from 1 to 6 inches, and as a matter of experience it was found that a 3-inch mirror sufficed for lines of from 80 to 100 miles, but 4-inch mirrors were needed for lines of 100 to 150 miles; the longest line demanded a square mirror of 6 inches (15 centimetres). The signaling or call lights used at the observing station consisted of reflectors from 8 to 12 inches (20 to 30 centimetres) in size; these powerful lights were easily discernible with the unaided eye by the heliotropers, even up to distances of 150 statute miles (240 kilometres), and served them for directing their mirrors at the beginning of an occupation of a station; they were also used for communication. On long easterly and westerly oriented lines the curious phenomenon of getting the reflected sunlight thrown to the station *at which the sun was already below the horizon*, was frequently observed, and at times lasted several minutes.

The horizontal directions at all the stations were observed with the 50-centimetre (20-inch) theodolite, originally in 19 and later on (since 1893) in but 17 positions of the azimuth circle. The intention was to secure two full sets in each position and to balance the number of observations of the morning and evening, but on account of unavoidable broken series their numbers had generally to be increased for each position. Respecting the time of observations, they were made from sunrise till 8 o'clock, and resumed in the afternoon at half past 4 o'clock and continued till sunset. The seeing was usually better in the morning than in the evening; excessive brilliancy of the light was screened off by breathing upon the ocular. The focal length of the instrument is 106 centimetres (42 inches), and the magnifying power, using the "half-inch" eyepiece, 83 diameters. A zero or reference mark was used at all stations; it generally was a black target of such dimensions as to present an apparent angular width of 16 seconds. To secure observations under a variety of atmospheric conditions, observations were extended over twenty or more days. Double zenith distances for heights of stations were observed at three different periods of the day, viz, between 6½ and 8 o'clock in the morning, between 11½ and 1 o'clock, and again between 4½ and 6 o'clock in the evening. This brought to light the fact that the minimum refraction of the day occurs late in the afternoon, even after the heat of the day has passed. As a rule these vertical angle measures were spread over not less than twelve days, at least for the main lines. Since the vertical circle was necessarily mounted eccentrically and at a given height above the station mark, the heliotrope also being at a certain elevation, a reduction of the observed zenith distances to refer them to a line "from ground to ground" was required. No simultaneous reciprocal zenith distances were obtained. The astronomic observations for time, azimuth, and latitude at or near the stations will be referred to in another place. The triangulation party also made observations of the magnetic declination, dip, and intensity, and meteorological notes were regularly kept. During the whole work the temperature of the air was never known to fall as low as 0° F., or − 18° C.

For the purpose of adequately describing the station and its approaches, a rough topographic survey was usually made of the region immediately surrounding it and covering from a few to, maybe, 20 square miles. This topographic knowledge was also desirable in order to form a judgment of the probable deflection of the vertical. Further work of much practical usefulness by the party was the determination of a comprehensive number of second order points for general topographic purposes. They were mostly principal mountain peaks, and were marked, when accessible, by a cairn conical

in shape, about 6 feet high and 4 feet in diameter at the base. Every principal station is marked by a copper bolt in the rock or masonry, but not infrequently bolts are placed in a north, south, east, or west direction (true) where bed rock permits and just *outside the ring wall.* These extra bolts can not be mistaken for the central or station bolt so long as the wall or masonry remains intact. The accompanying photographic illustrations will greatly assist in the formation of a vivid mental picture of the doings of the party.

In conclusion, it may be remarked that the conditions of the weather on these high mountains could not be called unfavorable during the ordinary field season, which lasts from about the first of June to the first of November, excepting, however, the period of thunderstorms in midsummer. These thunderstorms, on account of their persistency among the high mountains, have frequently given rise to much suffering, danger, and delay in the progress of the work. They would envelop or hover around the mountains for days in succession, accompanied by the most violent electrical discharges and thunderbolts imaginable. During such times the whole mountain top fairly hummed or hissed by virtue of escaping electricity, and sparks a couple of inches in length could easily be drawn from any exposed insulated object. These storms would usually set in about 11 o'clock in the morning and last till long after sunset. Though no fatality is, fortunately, to be recorded, they proved, nevertheless, the main cause of discomfort and danger to the party exposed to their fury. The highly attenuated state of the atmosphere, the icy blasts during stormy periods, often accompanied by hail and snow, contributed their share to the depressing and dismal feeling during such exposures. The experience of the heliotropers would seem to have been more perilous, for three of them were knocked down and rendered partly unconscious, while a tent, several signals, and a theodolite were demolished by lightning. The (so-called) equinoctial snowstorms which annually break over these mountains with surprising regularity were usually borne without concern. They arrive about the beginning of October, and, though sometimes severe and followed by intense cold, they seldom caused other than mere temporary interruption in the communication with the camp below.

A few words about the Indians may not be deemed out of place. Though numerically well represented, particularly in Colorado and Nevada, and frequent visitors at the surveyor's camp, their demeanor was uniformly unobtrusive and considerate. Though half civilized and fairly competent, their services were not desired or required, except occasionally for packing of wood and water for the heliotropers.

Notice had to be taken of the fact that the Salt Lake Base Net lies aside to the north of the main triangulation, and consequently some scheme had to be devised as to its most advantageous connection with the adjacent nets. Since the Wheeler Peak hexagon could not be broken up, it was decided to make the adjustment first with the Yolo Base and next by means of the known (adjusted) side, Mount Nebo-Tushar with the El Paso Base. The order of proceeding from east to west being retained in the publication, the connecting link, Mount Nebo-Tushar, will be found given in the Nevada series of triangles immediately *following* the present adjustment.

The distance between the lines Divide to Big Springs and Mount Nebo to Ibepah is about 780 kilometres or 485 statute miles; thence to Salt Lake Base 156 kilometres or 97 statute miles.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment, 1885–1895.*

Tushar, Piute County, Utah. August 28 to September 22, 1885. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from first figure adjustment.	Corrections from first and second figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″	″	″	″
	Beaver	0 00 00·000	±0·050	....	....	....	....	....
	Pioche	27 52 18·203	0·082	−0·107	18·310	+ ·086	....	18·396
	Wheeler Peak	67 17 12·102	0·120	−0·182	11·920	+ ·370	....	12·290
	Ibepah	96 32 40·081	0·086	−0·244	39·837	− ·392	....	39·445
	Mount Nebo	155 33 43·049	0·086	−0·155	43·204	·002	....	43·202
1	Wasatch	182 45 10·281	0·083	−0·228	10·509	....	− ·158	10·351
2	Mount Ellen	238 41 36·332	0·074	−0·102	36·230	....	+ ·325	36·555

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·68.

Mount Nebo, Juab County, Utah. June 16 to July 29, 1887. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.	Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and first figure adjustment.	Corrections from base-net, first and second figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″	″	″	″	″
	Azimuth Mark	0 00 00·000	±0·046	....	....	....	....	....	....
3	Patmos Head	99 26 42·277	0·096	−0·096	42·181	....	....	−0·179	42·002
4	Wasatch	155 13 16·508	0·091	−0·137	16·371	....	....	+0·215	16·586
	Tushar	194 36 40·046	0·090	−0·155	40·201	....	+ 0·227	....	40·428
	Wheeler Peak	242 40 45·694	0·075	−0·178	45·872	....	+0·059	....	45·931
	Ibepah	265 48 49·527	0·080	−0·011	49·516	−0·147	....	....	49·369
	Pilot Peak	299 41 13·102	0·070	0·199	12·903	−0·051	....	....	12·852
	Deseret	309 18 29·821	0·112	−0·219	29·602	−0·133	....	....	29·469
	Ogden Peak	350 55 13·527	0·063	−0·024	13·503	+0·330	....	....	13·833

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·61.

Patmos Head, Emery County, Utah. September 20 to October 19, 1890. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting direction from station adjustment.	Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		° ′ ″	″	″	″	″	″
	Azimuth Mark	0 00 00·000	±0·052	....	....	....	....
9	Tavaputs*	98 42 01·705	....	+0·012	01·717	−0·543	01·174
10	Mount Waas	149 29 05·105	0·088	−0·243	04·862	+0·214	05·076
11	Mount Ellen	207 09 05·158	0·073	+0·120	05·278	+0·011	05·289
12	Wasatch	257 55 46·352	0·071	+0·161	46·513	+0·367	46·880
13	Mount Nebo	297 05 30·693	0·074	−0·125	30·568	−0·049	30·519

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·67.

* Deduced from subordinate station "East Peak."

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment, 1885–1895*—Continued.

Wasatch, Sanpete County, Utah. August 1 to August 28, 1890. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·057	....	....	....	....
6	Mount Nebo	56	15	21·449	0·093	−0·149	21·300	−0·137	21·163
7	Patmos Head	141	19	25·325	0·109	+0·147	25·472	−0·379	25·093
8	Mount Ellen	228	22	19·686	0·090	−0·186	19·500	+0·276	19·776
5	Tushar	302	49	50·062	0·097	+0·244	50·306	+0·205	50·511

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·72.

Mount Waas, Grand County, Utah. July 12 to August 4, 1893. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·099	....	....	....	....
19	Mount Ellen	57	49	33·940	0·111	+0·138	34·078	−0·096	33·982
20	Patmos Head	124	44	59·552	0·113	−0·199	59·353	−0·187	59·166
21	Tavaputs	175	33	49·620	0·115	+0·060	49·680	+0·041	49·721
22	Treasury Mountain	239	14	21·538	0·096	+0·150	21·688	−0·002	21·686
23	Uncompahgre	273	50	31·107	0·116	−0·172	30·935	+0·243	31·178

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·95.

Mount Ellen, Piute County, Utah. July 31 to August 22, 1891. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·057	....	....	....	....
14	Tushar	121	30	16·898	0·078	−0·117	16·781	−0·052	16·729
15	Wasatch	171	06	54·549	0·075	−0·184	54·365	−0·244	54·121
16	Patmos Head	213	17	51·469	0·073	+0·105	51·574	−0·178	51·396
17	Mount Waas	268	43	14·308	0·077	+0·156	14·464	+0·245	14·709
18	Uncompahgre	287	44	08·352	0·078	0·000	08·352	+0·229	08·581

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·67.

Treasury Mountain, Gunnison County, Colorado. September 7 to September 21, 1893. 50-centimetre theodolite, No. 5. W. Eimbeck and J. Nelson, observers. June 24 to July 3, 1895. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·055	....	....	....	....
34	Mount Elbert	137	13	55·221	0·081*	+0·115	55·336	+0·374	55·710
35	Mount Ouray	189	27	23·506	$\left\{\begin{matrix}0·079\\0·081^*\end{matrix}\right\}$	−0·278	23·228	+0·086	23·314
36	Uncompahgre	255	51	26·886	0·067	+0·161	27·047	−0·111	26·936
37	Mount Waas	313	40	06·565	0·074	+0·126	06·691	−0·008	06·683
38	Tavaputs	349	02	28·072	0·092	−0·114	27·958	−0·341	27·617

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·58.

* Directions marked with a * depend upon the probable error ±0″·081 of Mount Ouray during the second occupation.

ROCKY MOUNTAIN RIDGES, AS SEEN FROM TREASURY MOUNTAIN, COLORADO, AND SHOWING UPPER CAMP, 107 METERS OR 351 FEET BELOW SUMMIT.

VIEW OF TREASURY MOUNTAIN COLORADO LOOKING WEST STATION AT EXTREME RIGHT OF SUMMIT

VIEW OF SUMMIT STATION ON UNCOMPAHGRE PEAK, COLORADO.

Altitude, 4,355 meters or 14,289 feet.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment, 1885–1895*—Continued.

Tavaputs, Garfield County, Colorado. September 27 to October 21, 1891. 50-centimetre theodolite No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting direction from station adjustment. ° ′ ″	Approximate probable error. ″	Reduction to sea level. ″	Resulting seconds. ″	Corrections from figure adjustment. ″	Final seconds in triangulation. ″
	Azimuth Mark	0 00 00·000	±0·063	....	....	....	....
24	Treasury Mountain	87 15 57·088	0·133	−0·164	56·924	−0·170	56·754
25	Uncompahgre	118 24 50·617	0·093	−0·280	50·337	−0·142	50·195
26	Mount Waas	168 13 53·097	0·084	+0·083	53·180	+0·020	53·200
27	Patmos Head	246 38 30·048	0·108	+0·012	30·060	+0·305	30·365

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·80.

Mount Elbert, Lake County, Colorado. July 9 to July 27, 1894. 30-centimetre theodolite, No. 146. P. A. Welker, observer.

No. of direction.	Objects observed.	° ′ ″	″	″	″	″	″
	Reference Mark	0 00 00·000	±0·066	....	....	....	....
45	Bison	176 00 16·394	0·100	+0·082	16·476	−0·296	16·180
46	Pikes Peak	199 22 22·810	0·087	−0·131	22·679	−0·251	22·930
47	Mount Ouray	261 34 00·272	0·095	−0·132	00·140	+0·448	00·588
48	Uncompahgre	313 14 38·887	0·082	+0·278	39·165	−0·194	39·359
49	Treasury Mountain	354 19 10·906	0·081	+0·104	11·010	−0·597	10·413

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″.67.

Uncompahgre, Hinsdale County, Colorado. August 20 to September 14, 1895. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	° ′ ″	″	″	″	″	″
	Azimuth Mark	0 00 00·000	±0·042	....	....	....	....
28	Mount Ellen	17 57 20·806	0·092	−0·017	20·789	+0·102	20·891
29	Mount Waas	34 57 59·980	0·088	−0·158	59·822	−0·016	59·806
30	Tavaputs	66 53 01·395	0·079	−0·177	01·218	+0·277	01·495
31	Treasury Mountain	122 33 55·729	0·089	−0·153	55·882	−0·130	55·752
32	Mount Elbert	142 52 07·460	0·095	+0·286	07·746	−0·211	07·535
33	Mount Ouray	175 40 48·147	0·065	−0·186	48·333	−0·022	48·311

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·54.

Plateau, Pueblo County, Colorado. July 25 to August 10, 1894, and September 24 to October 3, 1895. 30-centimetre theodolite, No. 118. F. D. Granger, observer.

No. of direction.	Objects observed.	° ′ ″	″	″	″	″	″
61	Pikes Peak	0 00 00·000	±0·098	−0·286	59·714	+0·072	59·786
62	Corral Bluffs	36 49 56·711	*0·095	−0·017	56·694	−0·193	56·501
63	Big Springs	73 43 16·565	{0·117, *0·091}	+0·118	16·683	−0·521	16·162
	Dry Camp	98 12 57·212	*0·106	+0·103	57·315	....	....
60	Mount Ouray	312 14 50·468	0·140	−0·019	50·449	+0·771	51·220

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·70.

* Directions marked with a * depend on the probable error ±0″·091 of Big Springs during the second occupation.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment, 1885–1895*—Continued.

Mount Ouray, Saguache County, Colorado. July 7 to July 31, 1894. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Reference Mark	0	00	00·000	±0·083	....	....	....	....
	Azimuth Signal	4	43	02·772	0·111	....	....	....	....
39	Uncompahgre	73	31	43·717	0·111	+0·184	43·901	+0·485	44·386
40	Treasury Mountain	134	01	14·063	0·111	−0·273	13·790	−0·032	13·758
41	Mount Elbert	169	02	48·693	0·090	−0·138	48·555	−0·590	47·965
42	Bison	217	35	11·921	0·157	+0·238	12·159	+0·372	12·531
43	Pikes Peak	248	16	47·712	0·095	+0·219	47·931	−0·145	47·786
44	Plateau	273	44	33·129	0·126	−0·003	33·126	+0·016	33·142

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·83.

Pikes Peak, El Paso County, Colorado. July 4 to August 4, 1895. 30-centimetre theodolite, No. 146. J. Nelson, observer. (W. Eimbeck, chief of party.)

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Azimuth Mark (Mount Rosa)	0	00	00·000	±0·099	....	....	....	....
55	Plateau	0	24	12·679	0·113	−0·108	12·571	−0·203	12·368
50	Mount Ouray	107	11	36·606	0·109	+0·210	36·816	−0·416	36·400
51	Mount Elbert	145	46	21·055	0·105	−0·143	20·912	+0·372	21·284
52	Bison	179	36	26·960	0·109	−0·250	26·710	−0·403	26·307
53	Divide	281	54	23·331	0·106	+0·128	23·459	+0·177	23·636
54	Big Springs	319	01	36·684	0·112	−0·035	36·649	+0·436	37·085

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·77.

Bison, Park County, Colorado. July 22 to August 16, 1894. 30-centimetre theodolite, No. 145. F. W. Perkins, observer.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Reference Mark	0	00	00·000	±0·045	....	....	....	....
57	Pikes Peak	8	05	07·928	0·058	−0·281	07·647	+0·139	07·786
58	Mount Ouray	84	58	58·189	0·071	+0·263	58·452	+0·303	58·755
59	Mount Elbert	130	53	06·787	0·066	+0·089	06·876	−0·399	06·477
56	Divide	331	53	10·001	0·067	−0·060	09·941	−0·059	09·882

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·55.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment, 1885–1895*—Completed.

Divide, El Paso County, Colorado. November 12 to November 19, 1879. 30-centimetre theodolite. No. 108. O. H. Tittmann, observer. August 1 to August 11, 1895. 30-centimetre theodolite, No. 118. F. D. Granger and J. B. Boutelle, observers.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea-level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″	″
	Holcolm Hills	0	00	00·00	±	−0·11	59·89	+0·191	....	00·081
	Big Springs	33	19	29·190	*0·134	−0·114	29·076	−0·926	....	28·150
	El Paso East Base	46	47	59·87	....	−0·08	59·79	+0·492	....	60·282
	Corral Bluffs	83	14	11·24	....	+0·08	11·32	−0·314	....	11·006
	El Paso West Base	98	42	24·31	....	+0·13	24·44	+0·557	....	24·997
64	Pikes Peak	126	59	19·980	*0·111	+0·240	20·220	....	−0·354	19·866
65	Bison	168	29	32·642	*0·088	−0·107	35·535	....	−0·181	32·354
							Mean	0·000		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·19 in 1879 and ± 0″·68 in 1895.

Big Springs, El Paso County, Colorado. August 21 to September 3, 1880. 30-centimetre theodolite, No. 108. O. H. Tittmann and G. F. Bird, observers. June 23 to July 6, 1895. 30 centimetre theodolite, No. 118. F. D. Granger and J. B. Boutelle, observers.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea-level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and first figure adjustment.	Corrections from base-net and second figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″		″
	Corral Bluffs	0	00	00·00	±	−0·10	59·90	+0·002	....	....	59·902
	El Paso East Base	27	23	27·51	....	−0·13	27·38	−0·268	....	....	27·112
	Divide	33	35	42·180	†0·115	−0·137	42·043	−0·370	....	....	41·673
	Holcolm Hills	54	42	04·99	....	−0·05	04·94	+0·636	....	....	05·576
	Square Bluffs	138	58	19·83	....	+0·06	19·89	....	+0·31	....	20·20
	Cramers Gulch	188	03	38·61	....	−0·10	38·51	....	−0·08	....	38·43
	Dry Camp	235	37	57·119	†0·228	−0·040	57·079	....	....	....	....
66	Plateau	279	28	24·329	†0·100	+0·101	24·430	....	....	+0·834	25·264
67	Pikes Peak	344	22	41·563	†0·121	−0·083	41·480	....	....	−0·244	41·236
							Mean		+0·038		

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·42 in 1880 and ± 0″·77 in 1895.

Weights to the individual directions entering into the triangulation were introduced, as explained in Part I and exemplified in the adjustment of the Yolo Base Net.

In the present case we have the number of directions = 67, the number of triangles = 23, and the average value of the probable error of an observed direction, as found by

* Directions marked with a * depend on the probable error ± 0″·134 of Big Springs during the second occupation.

† Directions marked with a * depend on the probable error ± 0″·115 of Divide during the second occupation.

station adjustments $e_s = \pm 0''.094$ and the same derived from the closing errors of the triangles, or $e_t = \pm 0''.27$. Hence $e_F^2 - e_s^2 = 0.0641$, and the relative weight-reciprocal to a direction $= \dfrac{14}{e_s^2 + 0.0641}$ where 14 is a convenient multiplier, which renders a large portion of the weight reciprocals equal to unity.

(*c*) *Figure adjustment.*

Observation equations.

No.	
1	$0 = +0.682 + (1) - (4) - (5) + (6)$
2	$0 = -0.221 - (1) + (2) + (5) - (8) - (14) + (15)$
3	$0 = +0.264 - (3) + (4) - (6) + (7) - (12) + (13)$
4	$0 = -1.077 - (7) + (8) - (11) + (12) - (15) + (16)$
5	$0 = -0.128 - (10) + (11) - (16) + (17) - (19) + (20)$
6	$0 = -1.270 - (9) + (10) - (20) + (21) - (26) + (27)$
7	$0 = +0.186 - (21) + (22) - (24) + (26) - (37) + (38)$
8	$0 = -0.233 - (22) + (23) - (29) + (31) - (36) + (37)$
9	$0 = +0.610 - (24) + (25) - (30) + (31) - (36) + (38)$
10	$0 = +0.472 - (17) + (18) + (19) - (23) - (28) + (29)$
11	$0 = +0.605 - (31) + (33) - (35) + (36) - (39) + (40)$
12	$0 = +1.356 - (31) + (32) - (34) + (36) - (48) + (49)$
13	$0 = +1.138 - (32) + (33) - (39) + (41) - (47) + (48)$
14	$0 = -1.003 - (41) + (42) - (45) + (47) - (58) + (59)$
15	$0 = -1.429 - (41) + (43) - (46) + (47) - (50) + (51)$
16	$0 = +0.767 - (45) + (46) - (51) + (52) - (57) + (59)$
17	$0 = +0.751 - (43) + (44) + (50) - (55) - (60) + (61)$
18	$0 = -0.951 - (52) + (53) - (56) + (57) - (64) + (65)$
19	$0 = +2.311 - (54) + (55) - (61) + (63) - (66) + (67)$
20	$0 = -0.187 - (53) - (54) + (64) - (67)$
21	$0 = -0.79 + 5.52(1) - 1.42(2) - 1.43(3) + 4.00(4) - 1.72(11) + 4.30(12) - 2.58(13) - 1.79(14)$
	$+ 4.11(15) - 2.32(16)$
22	$0 = -0.64 - 1.72(9) + 3.05(10) - 1.33(11) - 1.45(16) + 7.56(17) - 6.11(18) - 1.78(25)$
	$+ 2.21(26) - 0.43(27) - 6.88(28) + 10.26(29) - 3.38(30)$
23	$0 = -0.18 + 1.04(21) - 4.09(22) + 3.05(23) + 3.15(24) - 3.48(25) + 0.33(26) + 0.09(29)$
	$- 1.44(30) + 1.35(31)$
24	$0 = + 2.44 + 4.11(31) - 5.69(32) + 1.58(33) + 1.19(39) - 4.20(40) + 3.00(41) - 0.10(47)$
	$- 2.42(48) + 2.52(49)$
25	$0 = + 8.61 + 1.86(41) - 5.41(42) + 3.55(43) + 4.71(45) - 4.87(46) + 0.16(47) + 0.67(50)$
	$- 3.14(51) + 2.47(52)$
26	$0 = - 4.96 + 3.55(42) - 7.97(43) + 4.42(44) + 2.88(56) - 3.37(57) + 0.49(58) + 1.91(60)$
	$- 2.53(61) + 0.62(63) - 2.24(64) + 2.38(65) + 0.99(66) - 2.80(67)$
27	$0 = + 3.98 + 2.78(53) - 5.17(54) + 2.39(55) + 0.62(61) - 3.90(62) + 3.28(63) - 0.14(64)$
	$- 1.09(66)$
28	$0 = - 3.72 - 1.42(1) + 1.42(2) - 2.56(4) - 0.91(5) + 0.91(6) - 0.11(7) + 0.11(8) - 1.72(9)$
	$+ 1.72(10) + 1.72(11) - 1.72(12) + 1.79(14) - 1.79(15) - 1.45(16) + 1.45(17) + 0.90(19)$
	$- 0.90(20) - 3.05(22) + 3.05(23) - 0.34(24) + 0.77(26) - 0.43(27) + 0.09(29) - 1.67(31)$
	$- 1.58(33) - 1.63(34) + 1.63(35) + 2.97(37) - 2.97(38) + 1.19(39) - 1.19(40) - 3.55(42)$
	$+ 3.55(43) - 0.16(45) + 0.06(47) + 0.10(49) + 0.67(50) - 0.67(52) - 2.78(53) + 2.78(54)$
	$- 2.88(56) + 2.88(57) + 2.04(58) - 2.04(59) + 2.38(64) - 2.38(65) + 1.82(67)$

(*c*) *Figure adjustment*—Continued.

Correlate equations.

	$\frac{14}{p}$	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_{10}	C_{21}	C_{22}	C_{23}	C_{28}
(1)	1·0	+1	−1								+5·52			−1·42
(2)	1·0		+1								−1·42			+1·42
(3)	1·0			−1							−1·43			
(4)	1·0	−1		+1							+4·00			−2·56
(5)	1·0	−1	+1	...	....	...	...	....	....	. ..	....	....	..	−0·91
(6)	1·0	+1		−1										+0·91
(7)	1·1			+1	−1									−0·11
(8)	1·0		−1		+1									+0·11
(9)	1·0						−1					−1·72		−1·72
(10)	1·0	....	.. .	....	....	−1	+1	....	....	...	....	+3·05	....	+1·72
(11)	1·0				−1	+1					−1·72	−1·33		+1·72
(12)	1·0			−1	+1						+4·30			−1·72
(13)	1·0			+1							−2·58			
(14)	1·0		−1								−1·79			+1·79
(15)	1·0	....	+1	....	−1	....	...	....	....	....	+4·11	....	....	−1·79
(16)	1·0				+1	−1					−2·32	−1·45		−1·45
(17)	1·0					+1				−1		+7·56		+1·45
(18)	1·0									+1		−6·11		
(19)	1·1					−1				+1				+0·90
(20)	1·1	....	....	....	....	+1	−1	....	....	....	....	....	....	−0·90
(21)	1·1						+1	−1					+1·04	
(22)	1·0							+1	−1				−4·09	−3·05
(23)	1·1								+1	−1			+3·05	+3·05

Correlate equations—Continued.

	$\frac{14}{p}$	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{17}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{28}
(24)	1·1		−1		−1									+3·15				−0·34
(25)	1·0				+1								− 1·78	−3·48				
(26)	1·0	−1	+1										+ 2·21	+0·33				+0·77
(27)	1·1	+1											− 0·43					−0·43
(28)	1·0	....	....	....	....	−1	....	....	....	....	....	....	− 6·88	....	....	....	....	....
(29)	1·0			−1		+1							+10·26	+0·09				+0·09
(30)	1·0				−1								− 3·38	−1·44				
(31)	1·0			+1	+1		−1	−1						+1·35	+4·11			−1·67
(32)	1·0							+1	−1						−5·69			
(33)	1·0	....	....	....	....	....	+1		+1	....	....	....	....	....	+1·58	....	....	+1·58
(34)	1·0							−1										−1·63
(35)	1·0						−1											+1·63
(36)	1·0			−1	−1		+1	+1										
(37)	1·0		−1	+1														+2·97
(38)	1·0	....	+1		+1	....	....	....	....	....	....	....	....	....	....	....	....	−2·97
(39)	1·1						−1		−1	...	...	...			+1·19			+1·19
(40)	1·1						+1								−4·20			−1·19
(41)	1·0								+1	−1	−1				+3·00	+1·86		
(42)	1·2									+1						−5·41	+3·55	−3·55
(43)	1·0	....	....	....	....	....	....	....	....	....	+1	−1	....	....	....	+3·55	−7·97	+3·55
(44)	1·1											+1					+4·42	

(*c*) *Figure adjustment*—Continued.

Correlate equations—Completed.

	$\frac{14}{p}$	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}
(45)	1·0			−1		−1						+4·71			−0·16
(46)	1·0				−1	+1						−4·87			
(47)	1·0		−1	+1	+1						−0·10	+0·16			+0·06
(48)	1·0	−1	+1								−2·42				
(49)	1·0	+1									+2·52				+0·10
(50)	1·1	....	....	....	−1	....	+1	....	....	....	....	+0·67	....	....	+0.67
(51)	1·0				+1	−1						−3·14			
(52)	1·1					+1		−1				+2·47			−0·67
(53)	1·1							+1		−1				+2·78	−2·78
(54)	1·1								−1	+1				−5·17	+2·78
(55)	1·1	....	....	....	....	....	−1	....	+1	....	....	....	....	+2·39	....
(56)	1·0							−1					+2·88		−2·88
(57)	0·9					−1		+1					−3·37		+2·88
(58)	1·0			−1									+0·49		+2·04
(59)	1·0			+1		+1									−2·04
(60)	1·2	....	....	....	....	....	−1	....	....	....	....	....	+1·91	....	....
(61)	1·0						+1		−1				−2·53	+0·62	
(62)	1·0													−3·90	
(63)	1·0								+1				+0·62	+3·28	
(64)	1·1							−1		+1			−2·24	−0·14	+2·38
(65)	1·0	...	....	....	....	....	....	+1	....	....	....	....	+2·38	....	−2·38
(66)	1·0								−1				+0·99	−1·09	
(67)	1·1								+1	−1			−2·80		+1·8

2

Normal equations.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
1. 0=+0·682	+4·0	−2·0	−2·0													
2. 0=−0·221		+6·0		−2·0												
3. 0=+0·264			+6·1	−2·1												
4. 0=−1·077				+6·1	−2·0											
5. 0=−0·128	....	....	....	....	+6·2	−2·1	....	....	....	−2·1	....	....	....	....	....	....
6. 0=−1·270						+6·3	−2·1									
7. 0=+0·186							+6·2	−2·0	+2·1							
8. 0=−0·233								+6·1	+2·0	−2·1	−2·0	−2·0				
9. 0=+0·610									+6·1		−2·0	−2·0				
10. 0=+0·472	....	....	....	..	....	....	....	....	....	+6·2	....	....	....	....	....	....
11. 0=+0·605											+6·2	+2·0	+2·1			
12. 0=+1·356												+6·0	−2·0			
13. 0=+1·138													+6·1	−2·0	−2·0	
14. 0=−1·003														+6·2	+2·0	+2·0
15. 0=−1·429	....	....	....	....	....	....	....	...	....	....	....	....	....	....	+6·1	−2·0
16. 0=+0·767																+6·0

Normal equations—Continued.

	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}
1. 0=+0·682					+ 1·520							+ 2·960
2. 0=−0·221					− 1·040							− 1·760
3. 0=+0·264					− 1·450							− 1·871
4. 0=−1·077					− 0·410	− 0·120						− 2·869
5. 0=−0·128	....	....	....	....	+ 0·600	+ 4·630	......	......	......	......	......	+ 0·920
6. 0=−1·270						+ 2·087	+ 0·814					+ 3·187
7. 0=+0·186						+ 2·210	− 8·369					− 7·846
8. 0=−0·233						−10·260	+ 8·705	+ 4·110				+ 7·615
9. 0=+0·610						+ 1·600	− 4·155	− 4·110				− 4·266

(*c*) *Figure adjustment*—Completed.

Normal equations—Completed.

	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}
10. 0=+0·472	....	....	....	....	......	+ 3·470	− 3·265	......	......	......	......	− 3·725
11. 0=+0·605							− 1·350	− 8·459				− 0·93[illegible]
12. 0=+1·356							− 1·350	− 4·860				+ 3·400
13. 0=+1·138								+ 6·641	+ 1·700			+ 0·211
14. 0=−1·003								− 3·100	−12·902	+ 3·770		− 8·120
15. 0=−1·429	−2·1	....	....	....	......	......	......	− 3·100	+ 2·843	− 7·970	......	+ 2·873
16. 0=+0·767		−2·0							− 3·733	+ 3·033		− 5·209
17. 0=+0·751	+6·5		−2·1						− 2·813	+ 8·010	− 2·009	− 2·813
18. 0=−0·951		+6·2		−2·2					− 2·717	− 1·069	+ 3·212	· 1·847
19. 0=+2·311			+6·3	−2·2						− 0·920	+12·066	− 1·056
20. 0=−0·187	....	....	....	+4·4	......	......	......	......	......	+ 0·616	− 8·899	+ 6·732
21. 0=−0·79					+104·115	+ 5·652						− 37·646
22. 0=−0·64						+282·900	+12·714					+ 21·810
23. 0=−0·18							+55·189	+ 5·548				+ 19·537
24. 0=+2·44								+93·943	+ 5·564			+ 2·934
25. 0=+8·61	....	....	....	....	......	......	......	......	+114·175	−51·340	......	+ 33·578
26. 0=−4·96										+150·840	− 0·269	− 76·581
27. 0=+3·98											+71·749	− 24·678
28. 0=−3·72												+173·696

Resulting values of correlates.

$C_1 = -0·144\ 7$	$C_8 = -0·158\ 9$	$C_{15} = -0·018\ 5$	$C_{22} = -0·025\ 52$
$C_2 = +0·196\ 3$	$C_9 = -0·190\ 0$	$C_{16} = -0·146\ 5$	$C_{23} = -0·000\ 62$
$C_3 = +0·128\ 4$	$C_{10} = +0·073\ 5$	$C_{17} = -0·444\ 5$	$C_{24} = +0·002\ 15$
$C_4 = +0·456\ 1$	$C_{11} = +0·157\ 2$	$C_{18} = -0·072\ 4$	$C_{25} = -0·077\ 73$
$C_5 = +0·294\ 8$	$C_{12} = -0·616\ 9$	$C_{19} = -0·747\ 8$	$C_{26} = +0·103\ 54$
$C_6 = +0·330\ 2$	$C_{13} = -0·417\ 8$	$C_{20} = -0·510\ 2$	$C_{27} = -0·049\ 52$
$C_7 = +0·292\ 0$	$C_{14} = +0·052\ 0$	$C_{21} = +0·068\ 89$	$C_{28} = +0·149\ 2$

Corrections to angular directions.

(1) = −0·172 6	(18) = +0·229 4	(35) = +0·086 0	(52) = −0·402 7
(2) = +0·310 4	(19) = −0·095 7	(36) = −0·110 8	(53) = +0·176 8
(3) = −0·226 9	(20) = −0·186 7	(37) = −0·007 8	(54) = +0·436 0
(4) = +0·166 7	(21) = +0·041 4	(38) = −0·341 1	(55) = −0·203 4
(5) = +0·205 2	(22) = −0·001 7	(39) = +0·484 8	(56) = −0·059 1
(6) = −0·137 3	(23) = +0·242 9	(40) = −0·032 2	(57) = +0·139 4
(7) = −0·378 6	(24) = −0·170 2	(41) = −0·589 5	(58) = +0·303 1
(8) = +0·276 3	(25) = −0·142 4	(42) = +0·372 5	(59) = −0·398 9
(9) = −0·542 9	(26) = +0·020 1	(43) = −0·145 4	(60) = +0·770 8
(10) = +0·214 2	(27) = +0·304 7	(44) = +0·015 7	(61) = +0·072 0
(11) = +0·010 7	(28) = +0·102 1	(45) = −0·295 5	(62) = −0·193 1
(12) = +0·367 3	(29) = −0·016 1	(46) = +0·250 5	(63) = −0·521 2
(13) = −0·049 3	(30) = +0·277 2	(47) = +0·447 7	(64) = −0·353 6
(14) = −0·052 5	(31) = −0·130 4	(48) = +0·193 9	(65) = −0·181 1
(15) = −0·243 8	(32) = −0·211 3	(49) = −0·596 6	(66) = +0·796 3
(16) = −0·177 8	(33) = −0·021 5	(50) = −0·415 9	(67) = −0·281 6
(17) = +0·244 7	(34) = +0·373 7	(51) = +0·372 1	

(d) Adjusted triangles, Colorado and Utah.

No.	Stations.	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
1	Wasatch	113	25	30·994	−0·342	30·652	7·215	5·215 521 5	164 256·13
	Tushar	27	11	27·322	−0·173	27·149	7·214	4·912 716 1	81 792·99
	Mount Nebo	39	23	24·009	−0·167	23·842	7·214	5·055 349 2	113 592·39
				22·325			21·643		
2	Mount Ellen	49	36	37·584	−0·191	37·393	11·444	5·055 349 2	113 592·39
	Tushar	55	56	25·721	−0·483	26·204	11·444	5·091 864 9	123 556·31
	Wasatch	74	27	30·806	−0·071	30·735	11·444	5·157 427 5	143 690·32
				34·111			34·332		
3	Patmos Head	39	09	44·055	−0·417	43·638	7·384	4·912 716 1	81 792·99
	Wasatch	85	03	64·172	−0·241	63·931	7·385	5·110 737 8	129 043·98
	Mount Nebo	55	46	34·190	+0·394	34·584	7·384	5·029 765 2	107 094·02
				22·417			22·153		
4	Patmos Head	50	46	41·235	+0·356	41·591	11·183	5·091 864 9	123 556·31
	Mount Ellen	42	10	57·209	+0·066	57·275	11·183	5·029 765 2	107 094·02
	Wasatch	87	02	54·028	+0·655	54·683	11·183	5·202 170 6	159 283·42
				32·472			33·549		
5	Mount Waas	66	55	25·275	−0·091	25·184	16·237	5·202 170 6	159 283·42
	Mount Ellen	55	25	22·890	+0·422	23·312	16·236	5·153 974 3	142 552·33
	Patmos Head	57	39	60·416	−0·203	60·213	16·236	5·165 215 2	146 290·19
				48·581			48·709		
6	Tavaputs	78	24	36·880	+0·285	37·165	10·540	5·153 974 3	142 552·33
	Mount Waas	50	48	50·327	+0·228	50·555	10·541	5·052 264 3	112 788·37
	Patmos Head	50	46	63·145	+0·757	63·902	10·541	5·052 081 2	112 740·81
				30·352			31·622		
7	Treasury Mountain	35	22	21·267	−0·333	20·934	16·448	5·052 081 2	112 740·81
	Mount Waas	63	40	32·008	−0·043	31·965	16·448	5·241 969 1	174 569·80
	Tavaputs	80	57	56·256	+0·190	56·446	16·449	5·284 107 3	192 356·71
				49·531			49·345		
8	Uncompahgre	31	54	61·396	+0·293	61·689	15·384	5·052 081 2	112 740·81
	Mount Waas	98	16	41·255	+0·202	41·457	15·384	5·324 386 2	211 050·40
	Tavaputs	49	48	62·843	+0·163	63·006	15·384	5·211 992 4	162 926·74
				45·494			46·152		
9	Uncompahgre	87	35	56·060	−0·114	55·946	15·062	5·284 107 3	192 356·71
	Mount Waas	34	35	69·247	+0·244	69·491	15·061	5·038 702 0	109 320·60
	Treasury Mountain	57	48	39·644	+0·103	39·747	15·061	5·211 992 4	162 926·74
				44·951			45·184		

(*d*) *Adjusted triangles, Colorado and Utah*—Continued.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
10	Treasury Mountain	93	10	60·911	−0·230	60·681	16·126	5·324 386 2	211 050·40
	Uncompahgre	55	40	54·664	−0·408	54·256	16·126	5·241 969 1	174 569·80
	Tavaputs	31	08	53·413	+0·028	53·441	16·126	5·038 702 0	109 320·60
				48·988			48·378		
11	Uncompahgre	17	00	39·033	−0·118	38·915	11·864	5·165 215 2	146 290·19
	Mount Ellen	19	00	53·888	−0·015	53·873	11·864	5·211 992 4	162 926·74
	Mount Waas	143	58	63·143	−0·339	62·804	11·864	5·468 512 4	294 111·77
				36·064			35·592		
12	Mount Ouray	60	29	29·889	−0·517	29·372	8·518	5·038 702 0	109 320·60
	Uncompahgre	53	06	52·451	+0·109	52·560	8·518	5·002 040 2	100 470·89
	Treasury Mountain	66	23	63·819	−0·197	63·622	8·518	5·061 114 8	115 110·46
				26·159			25·554		
13	Mount Elbert	41	04	31·845	−0·790	31·055	4·688	5·038 702 0	109 320·60
	Uncompahgre	20	18	11·864	−0·081	11·783	4·688	4·761 404 1	57 730·33
	Treasury Mountain	118	37	31·711	−0·485	31·226	4·688	5·164 501 4	146 049·96
				15·420			14·064		
14	Mount Elbert	92	45	10·870	−1·044	09·826	3·879	5·002 040 2	100 470·89
	Mount Ouray	35	01	34·765	−0·557	34·208	3·880	4·761 404 1	57 730·33
	Treasury Mountain	52	13	27·892	−0·287	27·605	3·880	4·900 390 3	79 504·24
				13·527			11·639		
15	Mount Ouray	95	30	64·654	−1·074	63·580	7·710	5·164 501 4	146 049·96
	Uncompahgre	32	48	40·587	+0·190	40·777	7·709	4·900 390 3	79 504·24
	Mount Elbert	51	40	39·025	−0·254	38·771	7·709	5·061 114 8	115 110·46
				24·266			23·128		
16	Bison	45	54	08·424	−0·702	07·722	5·565	4·900 390 3	79 504·24
	Mount Ouray	48	32	23·604	+0·962	24·566	5·565	4·918 899 9	82 965·96
	Mount Elbert	85	33	43·664	+0·743	44·407	5·565	5·042 880 2	110 377·41
				15·692			16·695		
17	Pikes Peak	38	34	44·096	+0·788	44·884	7·454	4·900 390 3	79 504·24
	Mount Ouray	79	13	59·376	+0·444	59·820	7·454	5·097 790 9	125 253·81
	Mount Elbert	62	11	37·461	+0·197	37·658	7·454	5·052 211 9	112 774·75
				20·933			22·362		
18	Pikes Peak	72	24	49·894	+0·013	49·907	5·377	5·042 880 2	110 377·41
	Mount Ouray	30	41	35·772	−0·518	35·254	5·377	4·771 596 1	59 101·18
	Bison	76	53	50·805	+0·164	50·969	5·376	5·052 211 9	112 774·75
				16·471			16·130		

(*d*) *Adjusted triangles, Colorado and Utah*—Completed.

No.	Stations.	Observed angles.			Corrections.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
19	Bison	122	47	59 ·229	−0 ·538	58 ·691	3 ·487	5 ·097 790 9	125 253 ·81
	Pikes Peak	33	50	05 ·798	−0 ·775	05 ·023	3 ·488	4 ·918 899 9	82 965 ·96
	Mount Elbert	23	22	06 ·203	+0 ·546	06 ·749	3 ·488	4 ·771 596 1	59 101 ·18
				11 ·230			10 ·463		
20	Plateau	47	45	09 ·265	−0 ·699	08 ·566	5 ·985	5 ·052 211 9	112 774 ·75
	Mount Ouray	25	27	45 ·195	+0 ·161	45 ·356	5 ·985	4 ·816 210 3	65 495 ·32
	Pikes Peak	106	47	24 ·245	−0 ·213	24 ·032	5 ·984	5 ·163 930 8	145 858 ·19
				18 ·705			17 ·954		
21	Divide	41	30	12 ·315	+0 ·172	12 ·487	2 ·574	4 ·771 596 1	59 101 ·18
	Pikes Peak	102	17	56 ·749	+0 ·580	57 ·329	2 ·573	4 ·940 225 2	87 141 ·54
	Bison	36	11	57 ·706	+0 ·199	57 ·905	2 ·574	4 ·721 592 2	52 673 ·50
				6 ·770			7 ·721		
22	Big Springs	64	54	17 ·050	−1 ·078	15 ·972	2 ·543	4 ·816 210 3	65 495 ·32
	Plateau	73	43	16 ·969	−0 ·593	16 ·376	2 ·544	4 ·841 504 2	69 423 ·13
	Pikes Peak	41	22	35 ·922	−0 ·640	35 ·282	2 ·543	4 ·679 473 4	47 805 ·01
				9 ·941			7 ·630		
23	Big Springs	49	12	60 ·155	+0 ·282	60 ·437	1 ·867	4 ·721 592 2	52 673 ·50
	Pikes Peak	37	07	13 ·190	+0 ·259	13 ·449	1 ·867	4 ·623 059 0	41 981 ·60
	Divide	93	39	52 ·070	−0 ·354	51 ·716	1 ·868	4 ·841 504 2	69 423 ·13
				5 ·415			5 ·602		
24	Plateau	36	53	19 ·989	−0 ·328	19 ·661	1 ·290	4 ·509 545 8	32 325 ·54
	Corral Bluffs	62	35	....	....	09 ·571	1 ·290	4 ·679 473 4	47 805 ·01
	Big Springs	80	31	35 ·434	−0 ·796	34 ·638	1 ·290	4 ·725 242 8	53 118 ·13
							3 ·870		

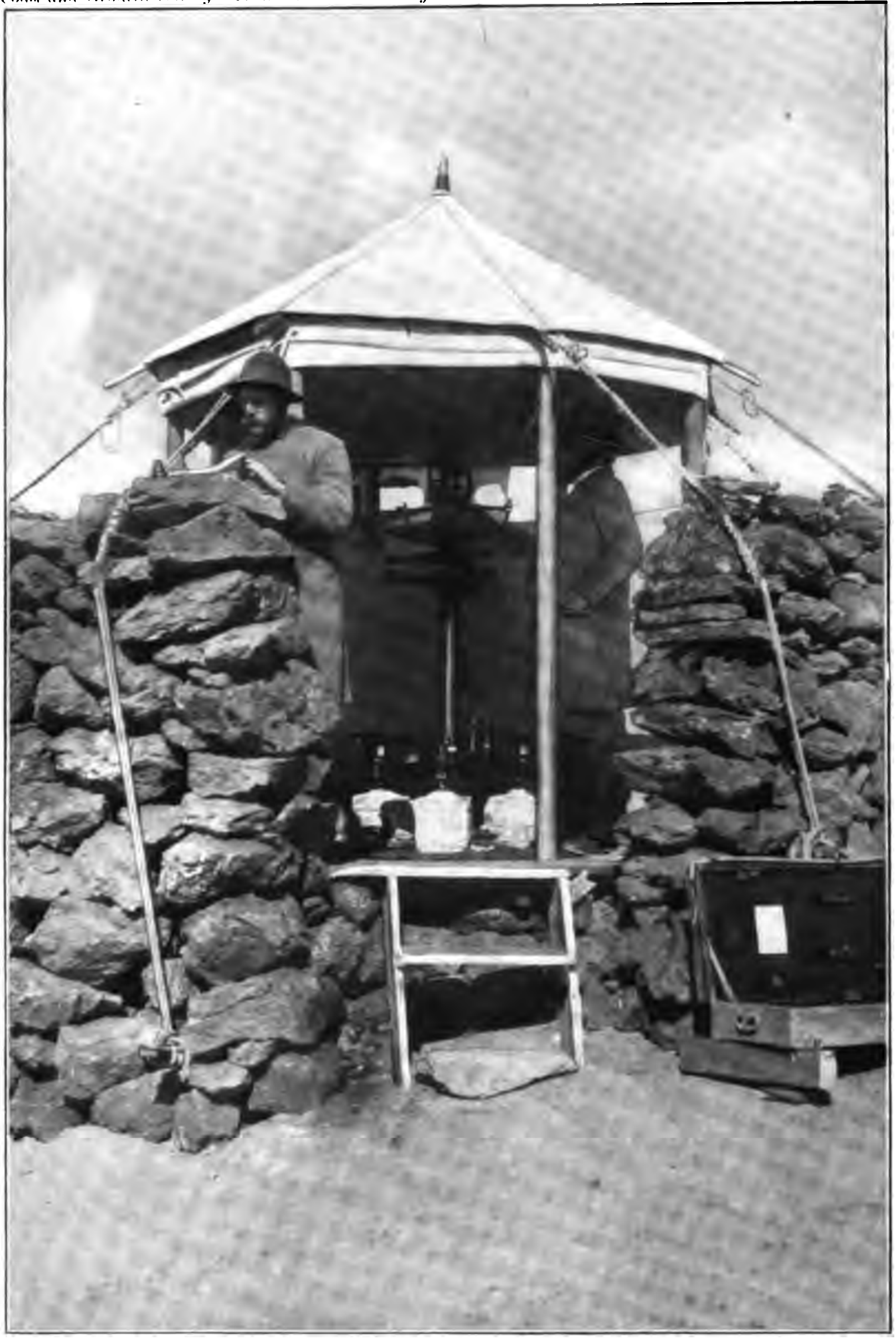
(*e*) *Precision of the adjusted triangulation.*

For a close estimate of the precision of the Rocky Mountain series of triangles, we find first the mean error of an angle resulting from the adjustment by the expression $m = \sqrt{\frac{2[pvv]}{c}}$, in which p may be taken as unity, $[vv] = 6{\cdot}09$, and $c = 28$; hence $m = \pm 0''{\cdot}66$.

The probable error in length of any line of the series due to the angular measures is found by the usual formulæ—

$$u_{a_n} = \tfrac{2}{3}\,(\delta_{a_n})^{-2}\,\Sigma_{a_1}^{a_n}\,[\delta_A^2 + \delta_A\delta_B + \delta_B^2] \text{ and } e_{a_n} = 0{\cdot}674\,5m\sqrt{u_{a_n}}$$

We will find first the probable error in length of the line Tavaputs-Mount Waas, which is about midway between the two base nets. Starting from the side Divide to



INTERIOR OF STATION ON UNCOMPAHGRE PEAK. OBSERVING HELIOTROPE ON MOUNT ELLEN.
DISTANCE 294.1 KILOMETERS OR 182¾ STATUTE MILES.

Big Springs of the El Paso Base Net, we have $\delta_{a_n} = 3{\cdot}86$, $\Sigma = 85{\cdot}0$ (eight triangles), $e_{a_n} = \pm 0{\cdot}87$ metre, $e_b = \pm 0{\cdot}32$ metre, and $e_1 = \pm 0{\cdot}93$ metre. Starting from the side Ibepah-Mount Nebo of the Salt Lake Base Net, $\Sigma = 31{\cdot}5$ (six triangles), $e_{a_n} = \pm 0{\cdot}53$ metre, $e_b = \pm 0{\cdot}41$ metre, and $e_2 = \pm 0{\cdot}67$. $e = \frac{e_1 e_2}{\sqrt{e_1^2 + e_2^2}} = \pm 0{\cdot}547$ metre which is about $\frac{1}{1\,306\,000}$ part of the length.

For the effect on the developed length of the arc we have approximately, the distances being measured between the middle points of the terminal lines projected onto the thirty-ninth parallel:

Terminal lines.	Distance.	Probable errors.	Average.	
	km.			*m.*
Divide to Big Springs and Tavaputs to Mount Waas	410·0	$\frac{1}{350\,000}$ and $\frac{1}{208\,000}$	$\frac{1}{259\,000}$	$\pm 1{\cdot}58$
Tavaputs to Mount Waas and Ibepah to Mount Nebo.	322·7	$\frac{1}{206\,000}$ and $\frac{1}{175\,000}$	$\frac{1}{236\,000}$	$\pm 1{\cdot}37$
	732·7			$\pm 2{\cdot}95$

(*f*) *Description of triangulation stations.*

Wasatch, Sanpete County, Utah; established in 1882 by W. Eimbeck. This station is located in the mountains, situated just west of Castle Valley, known locally as the Wasatch Range. It is about 18 miles east of the town of Mayfield, on a small table in the southern part of the range, situated between the heads of the North Fork of Muddy Creek and the South Fork of Ferron Creek.

The geodetic point is marked by a three-fourths-inch copper bolt leaded into a common limestone rock. In 1890 an additional bolt, 3½ inches long, was set on top of the old bolt and securely cemented in position, in order to make the mark more easily referred to. Around and over this was built a brick foundation pier for the theodolite, surrounded by a circular stone wall, with inner diameter of 11½ feet concentric to the station bolt, which was left standing. Reference marks are four bricks set on end, tops flush with surface of the ground, just outside the ring wall, with holes drilled in the tops and filled with plaster of Paris; one north 15° 34′ west, distant 8·25 feet; one south 54° 21′·5 east, distant 7·62 feet; one south 32° 12′ west, distant 7·88 feet, and one north 88° 21′ west, distant 7·62 feet, from the geodetic point.

Mount Ellen, Garfield County, Utah; established in 1882 by W. Eimbeck. This station is located on the northern summit of the Henry Mountains, about 18 miles south of Blue Valley, Grand County. Mount Ellen is a rounded conical-shaped peak covered with sharp irregular-shaped granite rocks, extending for 1 000 feet below its summit. It can be most readily approached by wagon road and trail from White's ranch, on the north side of Fremont River, in Blue Valley. The geodetic point is marked by a copper bolt set in a rock, which is itself embedded in the rock and dirt composing the peak. Around and over this was built the stone and brick foundation pier for the theodolite, capped with a stone slab, having a three-fourths-inch drill hole through it as a surface mark. This was surrounded by the usual stone ring wall, 11 feet inner diameter, concentric with the station bolt, which was left standing. Reference marks are 3 drill

holes, filled with plaster of Paris, in solid surface rock just outside the ring wall—one south 23° 35′ west, distant 7·9 feet; one north 35° 15′ west, distant 8 feet, and one north 83° 34′ east, distant 7·85 feet, from the geodetic point. The ring wall around the vertical circle station bearing north 38° 44′ west, distant 18·6 feet, and the latitude pier bearing south 5° 21′ west, distant 49·3 feet, were also left standing.

Patmos Head, Emery County, Utah; established in 1882 by W. Eimbeck. This station is situated in a range of mountains known as the West Tavaputs Plateau, about 12·5 miles north 72°·5 east from Sunnyside, a station on the Rio Grande Western Railroad. These mountains are known as "tables," and have a general trend somewhat west of north. The station is located on the highest point within several miles.

The geodetic point is marked by a copper bolt in a rock bedded in the ground, around and over which was built the stone foundation pier for the theodolite, capped with a stone slab having a drill hole through it, as a surface mark. The copper bolt is about 8½ inches below the drill hole. Around this was built the usual circular ring wall, 11 feet inner diameter, concentric to the station bolt, which was left standing. Reference marks are drill hole in bedded rock north 53° 16′ east, distant 8·5 feet; drill hole in bedded rock south 32° 53′ east, distant 8·58 feet; copper bolt south 16° 44′ east, distant 11·33 feet; and stump of tree north 89° 54′ west, distant 11 feet, from the geodetic point.

Mount Waas, Grand County, Utah; established in 1890 by W. Eimbeck. This station is located on the third principal prominent peak from the north end of the La Sal Mountains situated a short distance to the eastward of Grand River Valley. It is about 10 miles west of the boundary line between the States of Utah and Colorado and about 40 miles southeast from Thompson station, on the Rio Grande Western Railroad. The geodetic point is marked by a cross cut on a copper bolt set in a stone slab cemented to the bed rock, around and over which was built the stone foundation pier for the theodolite. It was surrounded by the usual circular stone ring wall, 10 feet inner diameter concentric with the station bolt, which wall was left standing. Reference marks are 4 drill holes, filled with plaster of Paris, just outside the ring-wall; one north 75° 41′ west, distant 7·5 feet; one north 6° 37′ east, distant 7·15 feet; one south 84° 15′ east, distant 7·25 feet, and one south 3° 58′ west, distant 7·35 feet, from the geodetic point.

Tavaputs, Garfield County, Colorado; established in 1890 by W. Eimbeck. This station is located on the southern edge of Book Mountains, about 3 miles east of the boundary line between the States of Utah and Colorado, about three-fourths of a mile to the eastward of Bitter Creek, and about 3 miles to the westward of West Salt Wash Creek; both creeks having their source a few miles north of the station. Fruita, a town on the Rio Grande Western Railroad, distant about 30 miles in an air line in a south-southeast direction, is the nearest railroad station and the readiest means of approach. The geodetic point is marked by a copper bolt set in a rock embedded in the ground, around and over which was built the masonry foundation pier for the theodolite. The pier was capped with a stone slab having a drill hole in the center, filled with plaster of Paris, 7¾ inches above the copper bolt, as a surface mark. This was surrounded by the usual circular stone ring-wall, 11 feet inner diameter concentric with the station bolt, which was left standing. Reference marks are 3 drill holes, filled with plaster of Paris; one south 37° 48′ east, distant 7·96 feet; one south 74° 41′ west, distant 7·96 feet, and one north 16° 31′ east, distant 7·88 feet, from the geodetic point. The brick astronomical pier, bearing north 8° 25′ west, distant 63 feet, was also left standing.

Uncompahgre, Hinsdale County, Colorado; established in 1890 by W. Eimbeck.

This station is on the summit of Uncompahgre Peak, Uncompahgre Mountains, one of the most prominent and best known peaks in southwestern Colorado. The summit is inaccessible except from the south side. Lake City, the terminus of a branch of the Denver and Rio Grande Railroad leaving the main road at Sapinero, distant about 8 miles, air line, southeast from the peak, is the nearest and most convenient railroad town. The geodetic point is on the north side of the summit about 10 feet from the edge of the perpendicular cliff of which this side of the mountain consists, and is marked by a cross cut in top of a half-inch copper bolt leaded into the solid rock. The surface mark is a half-inch hole in a brick cemented into the top of the masonry foundation pier, for the theodolite, built around and over the station bolt. The top of the brick is 4 inches above the bolt. The usual circular stone ring wall, inner diameter 11 feet concentric with station bolt, was left standing. Reference marks are 4 drill holes in the solid rock, filled with lead; one south 89° 58′ west, distant 9·35 feet; one north 0° 11′ west, distant 8·71 feet; one north 89° 56′ west, distant 9·4 feet, and one south 3° 37′ west, distant 8·12 feet, from the geodetic point. The brick latitude pier, bearing south 54° 05′ east, distant 50·11 feet, and the stone pendulum house, bearing south 28° 26′ east, distant 134·15 feet, were also left standing.

Treasury Mountain, Gunnison County, Colorado; established in 1890 by W. Eimbeck. This station is on the summit of Treasury Mountain, a prominent peak in the Elk Mountain Range, about 2 miles southeast of the mining town of Crystal and about 10 miles, air line, northwest from the town of Crested Butte, the terminus of a branch of the Denver and Rio Grande Railroad from Gunnison. The north side of the mountain is a precipitous cliff, dipping at an angle of about 70° for fully 2 000 feet to the head of Crystal Basin. About 500 feet to the west and 150 feet below the station is the entrance to the "Eureka" silver mine. The geodetic point is marked by a half-inch copper bolt set in the solid rock. The surface mark is a brick, having a half-inch hole in the center filled with plaster of Paris, cemented in the top of the masonry foundation pier, for the theodolite, built around and over the copper bolt. The top of the brick is 6½ inches above the bolt. The usual circular stone ring wall, inner diameter 10 feet, concentric with the station bolt, was left standing. Reference marks are 4 drill holes filled with plaster of Paris; one north 2° 40′ west, distant 7·85 feet; one north 87° 10′ east, distant 7·58 feet; one south 8° 35′ east, distant 7·38 feet, and one south 81° 45′ west, distant 7·83 feet, from the geodetic point. The brick latitude pier, bearing south 32° 10′ east, distant 102·13 feet, was also left standing.

Mount Ouray, Saguache County, Colorado; established in 1893 by W. Eimbeck. This station is on the summit of Mount Ouray, on the "Great Continental Divide," about 2½ miles in a northeasterly direction from Marshall Pass railroad station, the highest point on the Denver and Rio Grande (narrow gauge) Railroad, from which point the station is most readily reached by pack trail about 5½ miles long.

The geodetic point is marked by a cross on top of a five-eighths-inch copper bolt leaded into the solid rock. The surface mark is a brick, with a five-eighths-inch drill hole in its center filled with charcoal dust covered with plaster of Paris, set north and south in concrete in the top of the masonry foundation pier, for the theodolite, built around and over the station bolt. The top of the brick is 12⅝ inches above the bolt. The usual circular stone ring wall, 11 feet inner diameter concentric with the bolt, was left standing. Reference marks are drill holes filled with plaster of Paris, in the ends of four bricks set in concrete just outside the ring wall; one north 6° 11′ east, distant

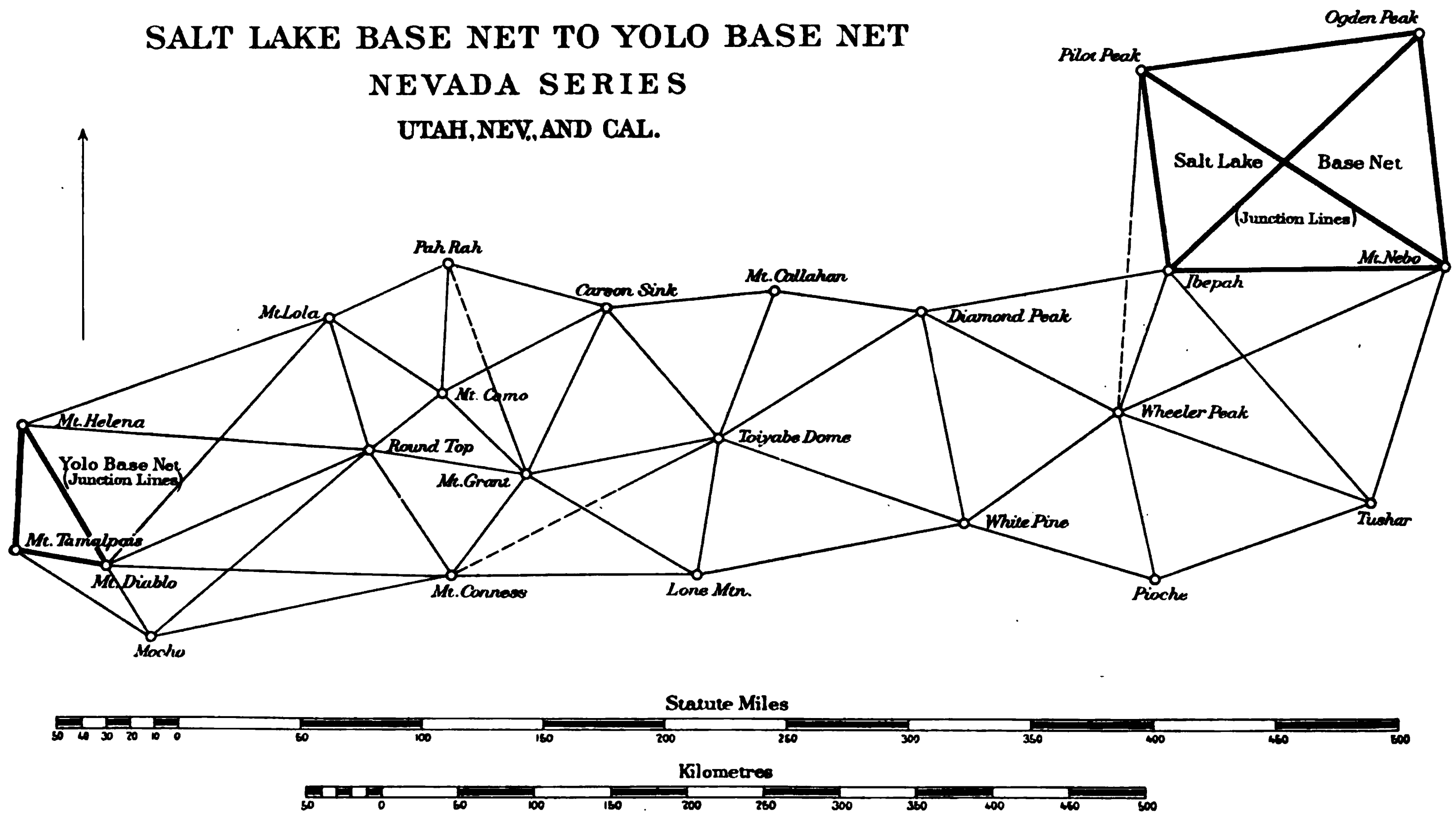
9 feet; one south 84° 06′ east, distant 8·95 feet; one south 5° 31′ west, distant 9·02 feet; and one north 83° 14′ west, distant 9·2 feet, from the geodetic point. The brick latitude pier, bearing north 8° 23′ east, distant 67.3 feet, was also left standing.

Mount Elbert, Saguache County, Colorado; established in 1894 by W. Eimbeck. This station is on the summit of the well-known peak called Mount Elbert, on the eastern edge of the Saguache Range, distant about 12½ miles southwest from Leadville. It can best be reached by good wagon roads from the post-office "Twin Lakes," called Dayton on the maps, situated at the southeastern base of the mountain, 17 miles from Leadville and 9 miles from Granite, a small mining town on the Denver and Rio Grande and Colorado Midland railroads. The summit, which is covered with snow during the greater part of the year, can be reached by a good pack trail, 7 miles long, from Twin Lakes post-office. The geodetic point is marked by a cross on a three-eighths-inch copper bolt leaded into a large surface rock. The surface mark is a hole drilled in a rock embedded in the top of the masonry foundation pier, for the theodolite, built around and over the copper bolt, the top of this rock being 5¼ inches above the bolt. A rock protection wall, 8 feet square on the inside and 2 feet thick, with opening to the north built around the station bolt, was left standing. Reference marks are four stones with holes drilled in them set approximately north, east, south, and west, under the protection wall, each distant 5 feet from the geodetic point.

Bison, Park County, Colorado; established in 1894 by W. Eimbeck. This station is on the highest point of the King Peak of the Tarryall Range, between Tarryall and Goose creeks, close to the ninth guide meridian west, in township 9 south. It can be reached by trail, 5 or 6 miles long, from Mountaindale post-office, which is 27 miles southeast from Jefferson, a station on the Denver, Lakewood and Golden branch of the Union Pacific Railroad, and 25 miles northwest from Florissant, a station on the Colorado Midland Railroad. The geodetic point was marked as follows: The surface of the rough granite was removed to a depth of about 6 inches, giving an approximately level space of 2 feet in diameter, in the center of which a wire nail was set, point upward, in a drill hole 2 inches deep and filled around with lead, leaving the point projecting three-eighths of an inch. Over this was built a rough pier of masonry for mounting the theodolite. Four holes were drilled bearing azimuths 0°, 180°, 240°, and 300°, in each of which seven 6-inch spikes for attaching the tent guys, and which will serve as reference marks, were driven and filled around with plaster of Paris.

Pikes Peak, El Paso County, Colorado; established in 1879 by O. H. Tittmann. This station is on the summit of the well known Pikes Peak, situated about 12 miles west of Colorado Springs and about 65 miles nearly south of Denver. The top of the peak, which is flat and nearly level, is a Government reservation covering many acres, to which easy access may be had by means of the Manitou and Pikes Peak cog railway. In 1894 this station was incorporated in the main scheme of triangulation coming from the west, and the geodetic point was re-marked by a wire nail, point upward, projecting about one-fourth inch above the surface. It was leaded into a drill hole in the concrete foundation of the masonry pier, 12·8 feet high, on which the theodolite was subsequently mounted. As left standing in 1895 after the occupation of the station, the top of this pier was 8 feet 10 inches above the point of the wire nail, covered with a triangular capstone having a drill hole in its center in the vertical of the station mark. Reference marks are the south chimney of the new signal service building south 75° 41′ east, distant 525·26 feet; the northwest corner of the old signal service building—now (1895) used as a stable—nearly southeast, distant

SALT LAKE BASE NET TO YOLO BASE NET
NEVADA SERIES
UTAH, NEV., AND CAL.



177·4 feet, and the latitude pier north 88° 42′ west, distant 18·11 feet, from the geodetic point. The nearest point of the bluff in a north-northwest direction is about 72 feet distant.

Plateau, Pueblo County, Colorado; established in 1894 by W. Eimbeck. This station is on M. Steele's ranch, on the highest ground at the north end of a high plateau about 9 miles north-northeast from Pueblo and 3½ miles northeast from Overton, Colorado. The geodetic point is marked by a half-gallon stone jug buried 3 feet below the surface of the ground, over which, as a subsurface mark, an inverted milk crock is placed, with a small hole drilled in the bottom. The crock is 2·9 feet below the surface. The surface mark is a granite post dressed to 6 inches square at the top, having two rectangular V-shaped grooves and the letters U.S.C.S. cut on the upper surface. The intersection of the grooves marks the geodetic point. Reference marks are two posts of lava stone set nearly in the meridian of the station, one 9·96 feet north and one 9·83 feet south of the geodetic point. Each post is 6 inches square and marked on top with a single diagonal groove terminating in an arrowhead which points toward the center of the station. There is a wire fence, marking the eastern boundary of Steele's property, just east of the station. The geodetic point is 252·9 feet from the north gatepost in this fence, and 168 feet from the second solid fence post north of the gatepost, where there is a slight angle to the northward in the fence.

10. THE NEVADA SERIES OF TRIANGLES, 1878–79–80–81–82–83, 1885, 1887, 1890.

(*a*) *Introduction.*

This section of the survey reaches from the Salt Lake Base in Utah to the Yolo Base in California; or, in other words, extends from the Wasatch Range on the east to the Coast Range on the west. We meet here with a distinct change of physical aspect and conditions from those characterizing the preceding section. Assistant Eimbeck remarks: The mountains of western Utah and of Nevada are neither so prominent nor so densely packed together as those of central and western Colorado. They are remarkable chiefly for parallelism and uniformity in an approximate northerly and southerly trend. These singular ranges, with their features preserved for a hundred miles, appear like solidified waves crested through folding. The corrugations, or parallel ranges, seem to follow each other at regular intervals throughout that large expanse of the State here under special consideration. While the valleys are nearly level and between 5 000 and 6 000 feet above the sea, the ridges rise on the average to over 10 000 feet (or 3 150 metres, nearly) and culminate at Wheeler Peak at an altitude of over 13 000 feet (3 973 metres, nearly). Their profile or crest lines are rugged and rocky and in some instances difficult of access. Though the topography may be intricate in ascending one of the transverse canyons, nearly every one of the stations was found to have an accessible slope. Excepting a few valleys in Utah and in west Nevada along the Carson and Humboldt, put partly under cultivation by irrigation, this entire basin is an arid and barren waste, irredeemable for want of flowing water; little or none is found anywhere except in the rills coming down from timber patches and meadows of the uplands of the most prominent ranges. The lower declivities of the ranges and the intervening low alkali lands covered with sage brush are equally sterile. The general aspect of the country is dull and monotonous. Only between the 7 000 and 11 000 feet levels are to be found an assemblage of clusters of pines, alpine meadows, and water supply from springs or melting snow. Except for an

occasional well dug at some way station, stretches of country from 40 to 60 miles would be without water. The only available railroad is the Central Pacific with its short branches, but it lies far to the north of the triangulation. To the westward of the Sierra Nevada, upon which three stations are located, the triangulation stretches across the flat valleys of the Sacramento and San Joaquin to the Diablo Range of mountains. As was the case with the Rocky Mountain section, the great drawback in the prosecution of the work was the want of means for the transportation of the material and supplies for men and beasts; quite frequently it became necessary, while traveling from station to station, to carry a full supply of water and fodder for the horses and mules. Roads and pack trails had to be built as soon as the base of the range was reached. The preparation of the mountain top for location of the camp, and the building of the foundation and wall of the station for the mounting and protection of the great theodolite, usually required much heavy rockwork and occasionally blasting. The circumvallation, while affording shelter, was needed for safety against the icy blasts of storms. The mode of living in these desolate mountains was that of the pioneer, diversified by many toilsome and dangerous climbs and trials of patience. Much that has been said respecting the movements of the party, its organization, labor, exposure, and work in the Rocky Mountain section applies also to the Nevada-California section.

The possibility of carrying out successfully a triangulation on the largest scale conformable to the natural topographic features of the country was established, attaining as well the practical solution of the problem demanded by the trigonometric connection of that part of the coast of California which lies in the vicinity of latitude 39° with the crest of the Sierra Nevada lying opposite to it. In 1874–75 Assistant W. Eimbeck was directed to make a reconnaissance for a main and subordinate triangulation over this region; his work extends from Monterey Bay on the south to Mount Shasta to the north, and eastward as far as the Walker and Pyramid lakes in Nevada. Here we find laid out the great figure known afterwards as the "Davidson quadrilateral," after Assistant G. Davidson, who directed its measurement. The reconnoissance farther to the eastward was prosecuted by Assistant A. F. Rodgers, who in 1878 had completed the scheme of triangles, on the same large scale, stretching across the remainder of Nevada and terminating at Mount Nebo of the Wasatch Range in Utah. This includes what is known as the "Great Hexagon," which has Wheeler Peak (Nevada) for its central point and comprises 53 690 square kilometres, or 20 730 square statute miles; adjacent to it to the west is another hexagon around the station Toiyabe Dome of but slightly inferior dimensions.

The instruments and methods of observing were the same as in the Rocky Mountain section. The whole work was carried out by Assistant W. Eimbeck or under his direct supervision. On an average two stations were occupied in a season—the occupation of each requiring about two months. The seasons, which were rather irregular, covered the time from May to December, the more favorable interval being from June to November. Scarcely a season passed without the party having been weather-bound by storms in October; while engaged upon the work on Wheeler Peak * the party was practically buried in a snowdrift 10 and 12 feet deep, the temperature of the air sunk to 20° below zero Fahrenheit, † and in order that the observations upon the distant stations

* At this station (in 1882) the brilliancy of the reflected moonlight suggested to the observer the selenotrope for occasional use at night; it was experimented with at stations Pioche and Nebo.

† Mr. Eimbeck states "the high snowdrifts which covered the living tents to within a foot or two of the apex saved the party from freezing to death."

might be continued, deep and broad trenches had to be cut through the snowdrifts in the line of sight. The party as well as the heliotropers at Tushar, Ibepah, and Mount Nebo suffered much from the intensity of this cold wave, and the value of the services of these men, two at each station, can not be overestimated.

The equalization of the number of measures of horizontal directions at a station taken in the forenoon and in the afternoon was first put into execution in 1880 in this section; its purpose was to eliminate any effect of unequal heating of the theodolite as well as to provide against possible lateral refraction along the lines of sight. Observations of zenith distances were made at three different periods of the day, as stated in the case of the Rocky Mountain work.

Between the middle of the line Mount Nebo to Ibepah and the middle of the line Mount Helena to Mount Diablo there is a distance of about 850 kilometres or 528 statute miles.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment.*

Mount Diablo, Contra Costa County, California. June 25 to September 8, 1876. 50-centimetre theodolite, No. 5. G. Davidson, C. Rockwell, and W. Eimbeck, observers. November 14 to December 29, 1884. 50-centimetre theodolite, No. 115. R. A. Marr, observer. G. Davidson, chief of party. June 28 to July 19, 1892. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″	″
	Mount Helena	0	00	00·000	±0·066	−0·082	59·918	−0·645	....	59·273
	Monticello	20	03	30·643	0·090	−0·032	30·611	0·102	....	30·509
	Vaca	20	19	59·505	0·098	−0·024	59·481	+0·319	....	59·800
	Azimuth Mark (Clayton)	25	49	17·204	{ 0·092 *0·074	−0·010	17·194	....	....	....
	Yolo Northwest Base	38	39	09·129	*0·115	0·000	09·129	+0·086	....	09·215
	Marysville Butte	38	40	30·881	0·094	+0·005	30·886	....	....	....
	Yolo Southeast Base	43	24	20·921	*0·106	0·000	20·921	+0·524	....	21·445
1	Mount Lola	73	06	31·834	0·089	+0·185	32·019	....	−0·206	31·813
	Pine Hill	76	14	00·524	0·106	+0·043	00·567	....	....	....
2	Round Top	97	32	04·551	0·107	+0·181	04·732	....	−0·035	04·697
3	Mount Conness	122	21	10·679	†0·062	+0·029	10·708	....	+0·345	11·053
4	Mocho	180	16	12·207	{ *0·111 †0·062	−0·080	12·127	....	+0·004	12·131
	Loma Prieta	211	22	06·404	*0·084	−0·011	06·393	....	....	....
	Sierra Morena	249	16	39·858	*0·092	+0·046	39·904	....	....	....
	Mount Tamalpais	310	12	09·226	0·095	−0·008	09·218	−0·047	....	09·171
	Ross Mountain	339	08	13·637	*0·087	−0·042	13·595	....	....	....
							Mean	+ ·023		

Probable error of a single observation of a direction (*D.* and *R.*) = $\pm 0''\cdot 72$.

* The directions marked by a * depend on the probable error $\pm 0''\cdot 074$ of the Azimuth Mark during the second occupation.

† The directions marked by a † depend on the probable error $\pm 0''\cdot 062$ of Mocho during the third occupation.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Mount Helena, Napa County, California. September 23 to November 26, 1876. 50-centimetre theodolite, No. 5. G. Davidson and W. Eimbeck, observers. August 14 to August 21, 1891. 50-centimetre theodolite, No. 115. E. F. Dickins, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″	″
	Mount Diablo	0	00	00·000	±0·058	−0·073	59·927	+0·183	....	00·110
	Mount Tamalpais	33	43	57·142	0·071	−0·004	57·138	+0·303	....	57·441
	Ross Mountain	102	52	47·356	....	+0·032	47·388	....	....	....
	Cold Spring	153	08	42·324	....	−0·045	42·279	....	....	....
	Mount Sanhedrin	193	02	53·251	....	−0·089	53·162	....	....	....
	Snow Mountain West	208	09	11·511	....	−0·038	11·473	....	....	....
	Snow Mountain East	208	37	44·912	0·059	....	....	....	....	....
	Azimuth Mark (Woods)	225	16	49·643	0·052	+0·007	49·650	....	....	....
	Marysville Butte	265	31	14·523	0·078	+0·042	14·565	....	....	....
5	Mount Lola	281	54	43·341	0·083	+0·140	43·481	....	−0·174	43·307
	Pine Hill	303	14	10·280	0·083	+0·004	10·284	....	....	....
6	Round Top	305	18	41·177	0·074	+0·005	41·182	....	−0·279	40·903
	Monticello	306	46	16·071	0·076	−0·002	16·069	+0·008	....	16·077
	Vaca	340	03	44·142	0·113	−0·045	44·097	−0·621	....	43·476
							Mean	−0·032		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·62.

Mount Tamalpais, Marin County, California. August 24 to October 9, 1882. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″	″
	Mount Diablo	0	00	00·000	±0·053	−0·011	59·989	+0·277	....	00·266
7	Mocho	23	47	56·302	0·064	−0·071	56·231	....	+0·422	56·653
	Sierra Morena	61	37	29·923	0·076	−0·037	29·886	....	....	....
	Ross Mountain	230	31	28·940	0·090	−0·043	28·897	....	....	....
	Mount Helena	263	31	35·075	0·086	−0·006	35·069	+0·054	....	35·123
	Monticello	289	01	42·852	0·072	+0·045	42·897	+0·048	....	42·945
	Vaca	307	25	02·177	0·062	+0·048	02·225	−0·380	....	01·845
							Mean	0·000		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·54.

SUMMIT OF ROUND TOP, CALIFORNIA, PRINCIPAL TRIANGULATION STATION ON THE SIERRA NEVADA.

Altitude, 3,165½ meters or 10,386 feet.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Mocho, Santa Clara County, California. August 19 to October 30, 1887. 50-centimetre theodolite, No. 115. J. S. Lawson, F. Morse, and P. A. Welker, observers. G. Davidson, chief of party.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·056	....	....	....	....
22	Round Top	66	13	15·043	0·136	+0·220	15·263	−0·018	15·245
23	Mount Conness	94	34	26·624	0·060	+0·140	26·764	+0·196	26·960
	Santa Ana	176	18	45·389	0·116	−0·057	45·332	....	....
	Mount Toro	203	17	21·473	0·132	+0·007	21·480	....	....
	Loma Prieta	232	55	15·468	0·096	+0·072	15·540	....	....
	Sierra Morena	284	31	49·647	0·085	+0·011	49·658	....	....
20	Mount Tamalpais	319	22	10·160	0·111	−0·046	10·114	−0·010	10·104
21	Mount Diablo	345	38	23·364	0·060	−0·076	23·288	−0·176	23·112

Probable error of a single obervation of a direction (*D.* and *R.*) = ±0″·70.

Round Top, Alpine County, California. August 17 to October 14, 1879. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·032	−0·159	59·841	....	....
16	Mount Lola	7	25	05·518	0·062	−0·121	05·397	−0·333	05·064
17	Mount Como	76	26	26·411	0·060	+0·184	26·595	+0·068	26·663
18	Mount Grant	122	47	32·511	0·078	−0·042	32·469	−0·066	32·535
19	Mount Conness	169	47	29·608	0·068	−0·247	29·361	+0·054	29·415
13	Mocho	254	03	23·038	0·053	+0·083	23·121	+0·216	23·337
14	Mount Diablo	270	44	49·863	0·051	+0·063	49·926	−0·082	49·844
15	Mount Helena	298	32	16·332	0·065	−0·003	16·329	+0·024	16·353
	Pine Hill	301	58	42·947	0·061	−0·006	42·941	....	....
	Snow Mountain East	316	57	47·335	0·047	....	....	....	....
	Maryville Butte	319	00	33·594	0·069	−0·029	33·565	....	....

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·48.

Mount Lola, Nevada County, California. June 18 to July 22, 1879. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·043	−0·157	59·843	....	....
	Lassens Butte	13	22	42·494	0·113	....	....	....	....
8	Pah-Rah	114	46	59·230	0·074	+0·137	59·367	−0·247	59·120
9	Mount Como	173	10	32·427	0·082	−0·158	32·269	−0·041	32·228
10	Round Top	212	23	00·222	0·109	−0·136	00·086	+0·375	00·461
	Pine Hill	267	17	07·756	0·084	+0·039	07·795	....	....
11	Mount Diablo	271	17	55·376	0·059	+0·075	55·451	+0·200	55·651
12	Mount Helena	300	07	03·738	0·059	+0·061	03·799	−0·248	03·551
	Marysville Butte	311	51	09·936	0·094	+0·016	09·952	....	....
	Snow Mountain East	321	58	42·323	0·073	....	....	....	....
	Mount Linn	340	58	41·684	0·086	....	....	....	....

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·[illegible]0.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Mount Conness, Tuolumne County, California. August 12 to September 5, 1890. 50-centimetre theodolite, No. 115. G. Davidson and J. J. Gilbert, observers.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·049	....	....	....	....
24	Mocho	24	52	40·751	0·080	+0·042	40·793	−0·050	40·743
25	Mount Diablo	38	02	02·708	0·071	+0·004	02·712	+0·054	02·766
26	Round Top	92	16	22·174	0·106	−0·210	21·964	−0·132	21·832
27	Mount Grant	164	09	13·672	0·114	+0·219	13·891	−0·269	13·622
28	Lone Mountain	216	47	03·954	0·098	+0·019	03·973	+0·373	04·346

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·70.

Pah-Rah, Washoe County, Nevada. October 9 to November 1, 1878. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	°	′	″	Approximate probable error. ″	Reduction to sea level. ″	Resulting seconds. ″	Corrections from figure adjustment. ″	Final seconds in triangulation. ″
34	Carson Sink	0	00	00·000	±0·112	−0·076	59·924	−0·341	59·583
35	Mount Como	77	55	16·780	0·108	0·000	16·780	+0·240	17·020
36	Mount Lola	140	32	22·464	0·108	+0·152	22·616	+0·072	22·688

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·88.

Mount Como, Douglas County, Nevada. August 14 to September 13, 1879. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	°	′	″	Approximate probable error. ″	Reduction to sea level. ″	Resulting seconds. ″	Corrections from figure adjustment. ″	Final seconds in triangulation. ″
29	Round Top	0	00	00·000	±0·074	+0·209	00·209	−0·059	00·150
30	Mount Lola	71	46	23·501	0·076	−0·164	23·337	+0·056	23·393
	Mount Davidson	103	37	44·337	0·080	....	....	....	....
31	Pah-Rah	130	46	01·424	0·101	0·000	01·424	−0·093	01·331
32	Carson Sink	190	07	07·903	0·107	+0·157	08·060	−0·135	07·925
33	Mount Grant	260	44	47·291	0·080	−0·224	47·067	+0·209	47·276

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·76.

Mount Grant, Esmeralda County, Nevada. October 18 to November 22, 1879. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	°	′	″	Approximate probable error. ″	Reduction to sea level. ″	Resulting seconds. ″	Corrections from figure adjustment. ″	Final seconds in triangulation. ″
39	Mount Como	0	00	00·000	±0·065	−0·183	59·817	−0·081	59·736
40	Pah-Rah	26	21	29·948	0·070	−0·122	29·826	−0·036	29·790
41	Carson Sink	72	36	09·224	0·065	+0·130	09·354	−0·058	09·296
	Desatoiya	94	40	54·247	0·095	....	....	....	....
42	Toiyabe Dome	126	03	33·966	0·075	+0·110	34·076	−0·355	33·721
43	Lone Mountain	167	19	06·701	0·109	−0·154	06·547	+0·429	06·976
37	Mount Conness	264	28	35·575	0·140	+0·240	35·815	+0·383	36·198
38	Round Top	325	36	06·884	0·067	−0·044	06·840	−0·139	06·701

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·80.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Lone Mountain, Esmeralda County, Nevada. October 25 to November 22, 1880. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Initial Mark	0	00	00·000	±0·058	...	....	....	...
58	Toiyabe Dome	58	39	45·478	0·062	+0·066	45·544	−0·219	45·325
	Monitor	92	22	53·441	0·074	....	....	....	....
59	White Pine	129	38	06·910	0·080	+0·090	07·000	+0·605	07·605
56	Mount Conness	319	09	57·283	0·335	+0·016	57·299	−0·225	57·074
57	Mount Grant	349	23	04·021	0·078	-0·197	03·824	−0·300	03·524

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·58.

Carson Sink, Churchill County, Nevada. June 20 to July 29, 1880. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

		°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·050	....	....	....	....
44	Mount Callahan	83	14	57·950	0·059	+0·054	58·004	−0·090	57·914
	Desatoiya	121	18	06·574	0·062	....	....	....	....
45	Toiyabe Dome	138	10	30·243	0·066	−0·235	30·008	−0·099	29·909
46	Mount Grant	204	15	04·478	0·054	+0·163	04·641	+0·096	04·737
47	Mount Como	241	01	38·655	0·050	+0·156	38·811	+0·005	38·816
48	Pah-Rah	283	45	37·956	0·070	−0·071	37·885	+0·087	37·972

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·51.

Toiyabe Dome, Nye County, Nevada. August 25 to September 22, 1880. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

		°	′	″	″	″	″	″	″
	Azimuth Mark (Ophir)	0	00	00·000	±0·041	....	....	....	....
51	Mount Callahan	6	08	01·852	0·071	+0·131	01·983	−0·243	01·740
52	Diamond Peak	43	55	59·428	0·060	+0·198	59·626	−0·244	59·382
53	White Pine	95	30	43·057	0·074	−0·140	42·917	−0·047	42·870
54	Lone Mountain	174	30	45·022	0·043	−0·050	45·072	+0·155	45·227
55	Mount Conness	228	02	57·450	0·335	+0·214	57·664	−0·014	57·650
49	Mount Grant	243	58	57·407	0·051	+0·098	57·505	+0·334	57·839
50	Carson Sink	304	27	30·784	0·076	−0·179	30·605	+0·022	30·627

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·58.

Mount Callahan, Lander County, Nevada. June 29 to July 29, 1881. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

		°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·066	....	....	....	....
60	Diamond Peak	68	03	52·686	0·046	−0·057	52.629	−0·157	52·472
	Prospect Peak	79	27	08·245	0·077	....	....	....	....
	Monitor	132	47	00·782	0·059	....	....	....	....
61	Toiyabe Dome	170	05	11·983	0·058	+0·149	12·132	+0·267	12·399
	Desatoiya	211	46	53·790	0·069	....	....	....	....
62	Carson Sink	233	29	35·431	0·054	+0·041	35·472	−0·109	35·363

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·51.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Diamond Peak, Eureka County, Nevada. August 25 to September 30, 1881. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·081	....	....	....	....
63	Ibepah	82	44	14·498	0·102	+0·083	14·581	−0·259	14·322
64	Wheeler Peak	119	24	33·338	0·076	−0·208	33·130	−0·033	33·097
65	White Pine	171	36	03·932	0·062	−0·085	03·847	+0·161	04·008
	Monitor	221	08	25·964	0·065	....	....	....	....
66	Toiyabe Dome	241	01	37·281	0·062	+0·210	37·491	+0·084	37·575
67	Mount Callahan	281	12	45·253	0·070	−0·059	45·194	−0·004	45·190

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·70.

White Pine, Nye County, Nevada. November 3 to December 14, 1881. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
	Reference Mark	0	00	00·000	±0·095	....	....	....	....
68	Lone Mountain	49	10	41·310	0·086	+0·064	41·374	−0·162	41·212
69	Toiyabe Dome	79	12	55·217	0·139	−0·157	55·060	+0·136	55·196
	Monitor	89	50	06·915	0·094	....	....	....	....
70	Diamond Peak	138	13	31·701	0·102	−0·082	31·619	−0·180	31·439
	Duckwater	155	01	34·934	0·090	....	....	....	....
71	Wheeler Peak	203	14	08·918	0·088	+0·255	09·173	+0·163	09·336
72	Pioche	254	57	46·943	0·094	−0·095	46·848	+0·065	46·913

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·90.

Wheeler Peak, White Pine County, Nevada. November 5 to November 23, 1882. August 3 to August 5, 1883. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	°	′	″	″	″	″	″	″
	Reference Mark	0	00	00·000	±0·065	....	....	....	....
75	Ibepah	31	20	23·220	0·093	+0·157	23·377	−0·268	23·109
76	Mount Nebo	78	03	32·172	0·077	+0·176	32·348	+0·498	32·846
77	Tushar	121	44	10·885	0·118	−0·160	10·725	−0·533	10·192
	Beaver	122	33	02·875	0·088	....	....	....	....
78	Pioche	179	47	38·224	0·101	−0·071	38·153	+0·253	38·406
73	White Pine	246	18	32·226	0·087	+0·215	32·441	−0·008	32·433
74	Diamond Peak	309	07	05·722	0·096	−0·177	05·545	−0·036	05·509

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·70.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Tushar, Piute County, Utah. August 28 to September 22, 1885. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Beaver	0	00	00·000	±0·050	....	....	....	....
82	Pioche	27	52	18·203	0·082	+0·107	18·310	+0·086	18·396
83	Wheeler Peak	67	17	12·102	0·120	−0·182	11·920	+0·370	12·290
84	Ibepah	96	32	40·081	0·086	−0·244	39·837	−0·392	39·445
85	Mount Nebo	155	33	43·049	0·086	+0·155	43·204	−0·002	43·202
	Wasatch	182	45	10·281	0·083	+0·228	10·509	....	....
	Mount Ellen	238	41	36·332	0·074	−0·102	36·230	....	....

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·68.

Pioche, Lincoln County, Nevada. September 6 to September 25, 1883. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed	Resulting direction from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·060	....	....	....	....
79	White Pine	91	11	42·118	0·061	−0·129	41·989	+0·170	42·159
80	Wheeler Peak	152	57	44·528	0·058	−0·106	44·422	−0·320	44·102
81	Tushar	235	30	04·866	0·073	+0·156	05·022	+0·167	05·189

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·53.

Pilot Peak, Elko County, Nevada. July 5 to July 22, 1889. 50-centimetre theodolite, No. 5. W. Eimbeck, observer. August 7 to August 18, 1892. 50-centimetre theodolite, No. 5. P. A. Welker, observer. (W. Eimbeck, chief of party.) August 6 to August 17, 1897. 50-centimetre theodolite, No. 5. P. A. Welker, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″	″
	Azimuth Mark, 1889	0	00	00·000	±0·049	....	....	....	....	....
	Reference Mark, 1892 and 1897	0	00	02·534	*0·055	....	....	....	....	....
	Cache	2	19	22·749	*0·089	....	....	....	....	....
	Oxford	36	43	40·495	*0·151	....	....	....	....	....
	Promontory	64	26	05·747	*0·065	+0·055	05·802	+0·198	....	06·000
	Ogden Peak	70	34	24·955	{0·066 *0·054}	+0·043	24·998	−0·145	....	24·853
	Antelope	79	13	44·735	*3·074	−0·008	44·727	+0·038	....	44·765
	Deseret	103	56	04·921	0·054	−0·169	04·752	−0·082	....	04·670
	Mount Nebo	111	06	37·692	0·069	−0·210	37·482	+0·021	....	37·503
	Ibepah	161	37	22·197	0·069	−0·047	22·150	−0·030	....	22·120
89	Wheeler Peak	172	37	22·903	0·075	+0·045	22·948	....	+0·104	23·052
							Mean	0·000		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·57.

* The directions marked by a * star depend on the probable error ±0″·054 of Ogden Peak during the second and third occupations.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Completed.

Ibepah, Juab County, Utah. August 23 to September 27, 1889. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·045	....	....	....	....	....
	Ogden Peak	25	43	47·159	0·092	+0·187	47·346	+0·013	....	47·359
	Deseret	34	55	41·025	0·089	+0·200	41·225	−0·192	....	41·033
	Mount Nebo	67	43	04·124	0·071	+0·001	04·125	+0·097	....	04·222
86	Tushar	117	31	04·280	0·077	−0·237	04·043	....	+0·262	04·305
87	Wheeler Peak	177	52	34·545	0·088	+0·166	34·711	....	+0·051	34·762
88	Diamond Peak	238	59	34·992	0·082	+0·064	35·056	....	−0·164	34·892
	Pilot Peak	332	05	10·271	0·086	−0·042	10·229	+0·082	....	10·311
							Mean	0·000		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·62.

Mount Nebo, Juab County, Utah. June 16 to July 29, 1887. 50-centimetre theodolite, No. 5. W. Eimbeck, observer.

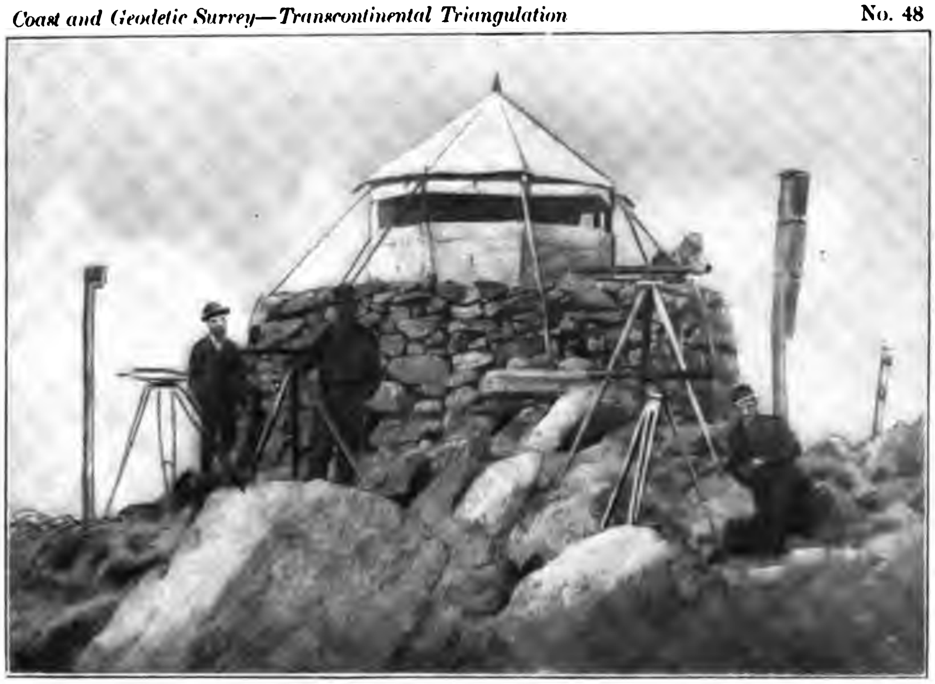
No. of direction.	Objects observed.	Resulting directions from station adjustment.			Approximate probable error.	Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″	″
	Azimuth Mark	0	00	00·000	±0·046	....	....	....	....	....
	Patmos Head	99	26	42·277	0·096	−0·096	42·181	....	....	....
	Wasatch	155	13	16·508	0·091	−0·137	16·371	....	....	....
90	Tushar	194	36	40·046	0·090	+0·155	40·201	....	+0·227	40·428
	Scipio*	213	51	58·848	....	+0·188	59·036	....	....	....
91	Wheeler Peak	242	40	45·694	0·075	+0·178	45·872	....	+0·059	45·931
	Ibepah	265	48	49·527	0·080	−0·011	49·516	−0·147	....	49·369
	Pilot Peak	299	41	13·102	0·070	−0·199	12·903	+0·051	....	12·852
	Deseret	309	18	29·821	0·112	−0·219	29·602	−0·133	....	29·469
	Onaqui*	315	22	52·056	0·070	−0·176	51·880	....	....	....
	Oquirrh*	332	45	19·604	0·066	−0·125	19·479	....	....	....
	Ogden Peak	350	55	13·527	0·063	−0·024	13·503	+0·330	....	13·833
	Draper*	353	14	45·190	0·097	−0·008	45·182	....	....	....
							Mean	0·000		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·61.

Weights to the individual directions entering into this triangulation were introduced as explained in Part I and exemplified in the adjustment of the Yolo Base Net.

In the present case we have the number of directions = 91, the number of triangles = 30, and the average value of the probable error of an observed direction as found by station adjustments $e_s = \pm 0''·080$; also the same derived from the closing errors of the

*Subordinate stations.



STATION AT IBEPAH, UTAH, SHOWING PROTECTION OF INSTRUMENT.

Altitude, 3,688½ meters or 12,101 feet.

triangles or $e_t = \pm 0''.20$; hence $e_t^2 - e_s^2 = 0.0336$, and the relative weight to a direction $= \dfrac{25}{e_s^2 + 0.0336}$, where 25 is a convenient multiplier which renders a large portion of the weights equal to unity.

Respecting the scheme finally selected, the station Mocho was admitted into it as an auxiliary to assist in crossing the wide valley between the Coast and the Sierra Nevada ranges. The triangle Mount Diablo, Mount Tamalpais, Mocho is very well measured, and the main triangulation is well rounded off with Mount Diablo as a central station.

(*c*) *Figure adjustment.*

Observation equations.

No.	
1	$0 = -0.275 - (4) + (7) - (20) + (21)$
2	$0 = +0.535 + (1) - (5) - (11) + (12)$
3	$0 = -0.295 + (2) - (6) - (14) + (15)$
4	$0 = +1.084 - (5) + (6) - (10) + (12) - (15) + (16)$
5	$0 = +0.101 - (2) + (4) - (13) + (14) - (21) + (22)$
6	$0 = -0.059 - (2) + (3) + (14) - (19) - (25) + (26)$
7	$0 = -0.134 - (3) + (4) - (21) + (23) - (24) + (25)$
8	$0 = -0.932 - (9) - (10) - (16) + (17) - (29) + (30)$
9	$0 = +0.111 - (8) + (9) - (30) + (31) - (35) + (36)$
10	$0 = +0.211 - (17) + (18) + (29) - (33) - (38) + (39)$
11	$0 = -0.276 - (32) + (33) - (39) + (41) - (46) + (47)$
12	$0 = -0.622 - (31) + (32) - (34) + (35) - (47) + (48)$
13	$0 = +0.673 - (18) + (19) - (26) + (27) - (37) + (38)$
14	$0 = +0.414 - (41) + (42) - (45) + (46) - (49) + (50)$
15	$0 = -1.043 - (42) + (43) + (49) - (54) - (57) + (58)$
16	$0 = -0.522 - (27) + (28) + (37) - (43) - (56) + (57)$
17	$0 = +0.651 - (44) + (45) - (50) + (51) - (61) + (62)$
18	$0 = -0.334 - (51) + (52) - (60) + (61) - (66) + (67)$
19	$0 = -1.324 - (53) + (54) - (58) + (59) - (68) + (69)$
20	$0 = +0.195 - (52) + (53) - (65) + (66) - (69) + (70)$
21	$0 = -0.510 - (64) + (65) - (70) + (71) - (73) + (74)$
22	$0 = +0.848 - (71) + (72) + (73) - (78) - (79) + (80)$
23	$0 = -1.557 - (77) + (78) - (80) + (81) - (82) + (83)$
24	$0 = +0.222 - (63) + (64) - (74) + (75) - (87) + (88)$
25	$0 = +1.573 - (76) + (77) - (83) + (85) - (90) + (91)$
26	$0 = -0.759 - (75) + (76) + (87) - (91)$
27	$0 = -0.424 - (84) + (85) + (86) - (90)$
28	$0 = +4.93 - 1.49(6) - 4.77(7) - 7.02(13) + 11.02(14) - 4.00(15) - 4.27(20) + 4.62(21) - 0.35(22)$
29	$0 = +1.83 + 4.64(1) - 4.92(2) - 4.87(5) + 6.36(6) - 1.19(10) + 1.27(11) - 0.08(12)$
30	$0 = -3.59 - 0.27(2) + 1.32(3) - 1.05(4) + 7.23(13) - 7.02(14) - 0.21(19) - 8.13(24) + 9.01(25) - 0.88(26)$
31	$0 = +0.60 - 4.64(1) + 9.19(2) - 4.55(3) - 2.58(9) + 3.85(10) - 1.27(11) - 1.52(25) + 2.21(26) - 0.69(27) + 0.35(29) - 0.69(30) + 0.34(33) - 1.16(37) + 4.24(38) - 3.08(39)$

(*c*) *Figure adjustment*—Continued.

Observation equations—Completed.

No.	
32	$0 = +1.97 - 1.30(8) + 3.88(9) - 2.58(10) - 0.81(16) + 2.82(17) - 2.01(18) + 4.80(31) - 4.80(33)$ $+ 1.09(35) - 1.09(36) - 3.08(38) + 12.13(39) - 9.05(40)$
33	$0 = -1.66 - 4.80(31) + 4.80(33) - 0.45(34) + 0.45(35) - 8.39(39) + 9.05(40) - 0.66(41)$ $- 2.82(46) + 5.10(47) - 2.28(48)$
34	$0 = +0.33 - 2.01(17) + 3.97(18) - 1.96(19) - 0.69(26) + 2.30(27) - 1.61(28) + 0.34(29)$ $- 0.74(32) + 0.40(33) - 0.93(45) + 3.75(46) - 2.82(47) + 1.98(49) - 1.19(50) - 0.79(54)$ $- 3.61(56) + 4.41(57) - 0.80(58)$
35	$0 = +8.55 + 1.61(27) - 1.61(28) - 4.38(37) + 4.38(42) - 10.97(49) - 0.79(54) + 11.76(55)$ $- 3.61(56) + 4.41(57) - 0.80(58)$
36	$0 = +1.22 - 1.56(41) + 3.96(42) - 2.40(43) - 1.48(44) + 2.41(45) - 0.93(46) - 0.80(57)$ $+ 1.52(58) - 0.73(59) + 0.45(60) + 0.61(61) - 1.05(62) - 0.79(65) + 3.28(66) - 2.49(67)$ $- 3.64(68) + 4.91(69) - 1.27(70)$
37	$0 = -3.72 - 2.83(63) + 4.46(64) - 1.63(65) - 0.98(70) + 2.64(71) - 1.66(72) - 1.13(79)$ $+ 1.41(80) - 0.28(81) - 2.56(82) + 6.32(83) - 3.76(84) - 1.20(86) + 2.36(87) - 1.16(88)$
38	$0 = -1.72 + 2.00(75) - 1.98(76) - 0.02(77) + 3.76(83) - 5.02(84) + 1.26(85) + 0.72(90)$ $- 4.93(91)$
39	$0 = -3.34 - 1.98(75) + 1.98(76) - 7.97(87) + 18.80(89) + 4.93(91)$
40	$0 = -8.55 - 4.55(2) + 4.55(3) - 1.49(6) + 4.00(14) - 4.00(15) - 1.96(18) + 1.96(19)$ $+ 1.52(25) - 1.52(26) - 1.61(27) + 1.61(28) + 1.16(37) - 1.16(38) - 2.40(42) + 2.40(43)$ $- 0.79(49) - 1.67(52) + 1.67(53) + 0.79(54) + 3.61(56) - 3.61(57) - 0.73(58) + 0.73(59)$ $- 2.83(63) + 2.83(64) + 0.79(65) - 0.79(66) + 3.64(68) - 3.64(69) - 0.98(70) + 0.98(71)$ $+ 1.08(73) - 1.08(74) - 1.98(75) + 1.98(76) + 1.16(87) - 1.16(88) + 4.93(91)$

Correlate equations.

v.	$\frac{25}{p}$	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{13}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{34}	C_{40}
(1)	1.0		+1											+4.64		−4.64			
(2)	1.1			+1		−1	−1							−4.92	−0.27	+9.19			−4.55
(3)	0.9						+1	−1							+1.32	−4.55			+4.55
(4)	1.0	−1				+1		+1							−1.05				
(5)	1.0	...	−1	...	−1	...	....	....	....	....	....	....	....	−4.87	....	....	....	....	....
(6)	1.0			−1	+1								−1.49	+6.36					1.49
(7)	0.9	+1											−4.77						
(8)	1.0									−1							−1.30		
(9)	1.0								−1	+1						−2.58	+3.88		
(10)	1.1	...	...	...	−1	..	....	....	+1	...	....	....	....	−1.19	....	+3.85	−2.58	....	....
(11)	0.9		−1											+1.27		−1.27			
(12)	0.9		+1		+1									−0.08					
(13)	0.9					−1							−7.02		+7.23				
(14)	0.9			−1		+1	+1						+11.02		−7.02				+4.00
(15)	0.9	...	...	+1	−1	...	....	....	....	....	....	....	−4.00	....	....	....	....	...	−4.00
(16)	0.9				+1				−1								−0.81		
(17)	0.9								+1		−1						+2.82	−2.01	
(18)	1.0										+1	−1					−2.01	+3.97	−1.96
(19)	1.0						−1					+1			−0.21			−1.96	+1.96
(20)	1.1	−1	.	...	...	...	....	....	....	....	....	....	−4.27	....	....	....	....	....	....
(21)	0.9	+1				−1		−1					+4.62						
(22)	1.3					+1							−0.35						
(23)	0.9							+1											

(c) *Figure adjustment*—Continued.

Correlate equations—Continued.

v.	25/p	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C30	C31	C32	C33	C34	C35	C36	C40
(24)	1·0		−1											−8·13							
(25)	1·0	−1	+1											+9·01	−1·52						+1·52
(26)	1·1	+1							−1					−0·88	+2·21			−0·69			−1·52
(27)	1·2								+1			−1			−0·69			+2·30	+1·61		−1·61
(28)	1·1	...	...	...	...	..	...	...	...	...	...	+1	...	....	....	....	....	−1·61	−1·61	...	+1·61
(29)	1·0			−1		+1									+0·35			+0·34			
(30)	1·0			+1	−1										−0·69						
(31)	1·1				+1			−1								+4·80	−4·80				
(32)	1·1						−1	+1										−0·74			
(33)	1·0	...	...	...	...	−1	+1	...	...	...	...	...	...	....	+0·34	−4·80	+4·80	+0·40			
(34)	1·2							−1									−0·45				
(35)	1·1				−1			+1								+1·09	+0·45				
(36)	1·1				+1											−1·09					
(37)	1·3								−1			+1			−1·16				−4·38		+1·16
(38)	1·0	...	..	...	...	−1	...	...	+1	...	...	...	...	....	+4·24	−3·08		....	....	....	−1·16
(39)	0·9					+1	−1								−3·08	+12·13	−8·39				
(40)	1·0															−9·05	+9·05				
(41)	0·9						+1			−1							−0·66			−1·56	
(42)	1·0									+1	−1								+4·38	+3·96	−2·40
(43)	1·1	...	...	...	...	...	...	...	...		+1	−1		....	....	....	....	....	....	−2·40	+2·40
(44)	0·9												−1							−1·48	
(45)	1·0									−1			+1					−0·93		+2·41	
(46)	0·9						−1			+1							−2·82	+3·75		−0·93	
(47)	0·9						+1	−1									+5·10	−2·82			
(48)	1·0	...	...	...	...	...	...	+1	...	...	...	...	...	....	....	....	−2·28	....	....	....	....

Correlate equations—Continued.

v.	25/p	C14	C15	C16	C17	C18	C19	C20	C21	C22	C24	C34	C35	C36	C37	C40
(49)	0·9	−1	+1									+1·98	−10·97			−0·79
(50)	1·0	+1			−1							−1·19				
(51)	1·0				+1	−1										
(52)	0·9					+1		−1								−1·67
(53)	1·0	...	...	...	...	...	−1	+1	....	....	....	....	....	....	....	+1·67
(54)	0·9		−1				+1					−0·79	−0·79			+0·79
(55)	3·6												+11·76			
(56)	3·6			−1								−3·61	−3·61			+3·61
(57)	1·0		−1	+1								+4·41	+4·41	−0·80		−3·61
(58)	0·9	...	+1	...	...	...	−1	...	....	....	....	−0·80	−0·80	+1·52	....	−0·73
(59)	1·0						+1							−0·73		+0·73
(60)	0·9					−1								+0·45		
(61)	0·9				−1	+1								+0·61		
(62)	0·9				+1									−1·05		
(63)	1·1	...	...	...	...	...	...	...	....	....	−1	....	....	....	−2·83	−2·83
(64)	1·0								−1		+1				+4·46	+2·83
(65)	0·9							−1	+1					−0·79	−1·63	+0·79
(66)	0·9					−1		+1						+3·28		−0·79
(67)	1·0					+1								−2·49		
(68)	1·0	...	...	...	...	...	−1	...	....	....	....	....	....	−3·64	....	+3·64
(69)	1·3						+1	−1						+4·91		−3·64
(70)	1·1							+1	−1					−1·27	−0·98	−0·98
(71)	1·0								+1	−1					+2·64	+0·98
(72)	1·1									+1					−1·66	

(c) *Figure adjustment*—Continued.

Correlate equations—Completed.

$v.$	$\frac{25}{p}$	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{37}	C_{38}	C_{39}	C_{40}
(73)	1·0	−1	+1									+1·08
(74)	1·1	+1			−1							−1·08
(75)	1·1				+1		−1			+2·00	− 1·98	−1·98
(76)	1·0					−1	+1			−1·98	+ 1·98	+1·98
(77)	1·2	....	....	−1	....	+1	....	....	....	−0·02	....	....
(78)	1·1		−1	+1								
(79)	0·9		−1						−1·13			
(80)	0·9		+1	−1					+1·41			
(81)	1·0			+1					−0·28			
(82)	1·0	....	....	−1	....	....	....	....	−2·56	...	....	....
(83)	1·2			+1		−1			+6·32	+3·76		
(84)	1·0							−1	−3·76	−5·02		
(85)	1·0					+1		+1		+1·26		
(86)	1·0							+1	−1·20			
(87)	1·0	....	....	....	−1	....	+1	...	+2·36	....	− 7·97	+1·16
(88)	1·0				+1				−1·16			−1·16
(89)	1·0										+18·80	
(90)	1·0					−1		−1		+0·72		
(91)	1·0					+1	−1			−4·93	+ 4·93	+4·93

Normal equations.

		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
1	0=−0·275	+3·9				−1·9		−1·9						
2	0=+0·535		+3·8		+1·9									
3	0=−0·295			+3·9	−1·9	−2·0	−2·0							
4	0=+1·084				+5·8				−2·0					
5	0=+0·101	....	....	....	....	+6·1	+2·0	+1·9	....	....	....	....	....	....
6	0=−0·059						+6·0	−1·9						−2·1
7	0=−0·134							+5·7						
8	0=−0·932								+5·9	−2·0	−1·9			
9	0=+0·111									+6·3			−2·2	
10	0=+0·211	....	....	....	....	....	....	....	....	....	+5·8	−1·9	....	−2·0
11	0=−0·276											+5·7	−2·0	
12	0=−0·622												+6·4	
13	0=+0·673													+6·6

(*c*) *Figure adjustment*—Continued.

Normal equations—Continued.

		C₁₄	C₁₅	C₁₆	C₁₇	C₁₈	C₁₉	C₂₀	C₂₁	C₂₂	C₂₃	C₂₄	C₂₅	C₂₆
11	o=−o·276	−1·8												
13	o=+o·673			−2·5										
14	o=+o·414	+5·7	−1·9		−2·0									
15	o=−1·043		+5·8	−2·1			−1·8							
16	o=−o·522	....	....	+9·3	....	....	....	....	....	....	....	....	....	....
17	o=+o·651				+5·7	−1·9								
18	o=−o·334					+5·6		−1·8						
19	o=−1·324						+6·1	−2·3						
20	o=+o·195							+6·1	−2·0					
21	o=−o·510	....	....	....	....	....	....	....	+6·1	−2·0	....	−2·1	....	....
22	o=+o·848									+6·0	−2·0			
23	o=−1·557										+6·4		−2·4	
24	o=+o·222											+6·3		−2·1
25	o=+1·573												+6·4	−2·0
26	o=−o·759	....	....	....	....	....	....	....	....	....	....	....	....	+4·1

Normal equations—Continued.

		C₂₇	C₂₈	C₂₉	C₃₀	C₃₁	C₃₂	C₃₃
1	o=−o·275		+ 4·56		+ 1·05			
2	o=+o·535			+ 8·30		− 3·50		
3	o=−o·295		−12·03	−11·77	+ 6·02	+10·11		
4	o=+1·084		+ 2·11	+12·47		− 4·24	+ 2·11	
5	o=+o·101	....	+11·62	+ 5·41	−13·58	−10·11	....	....
6	o=−o·059		+ 9·92	+ 5·41	−14·60	−10·25		
7	o=−o·134		− 4·16		+14·90	+ 2·58		
8	o=−o·932			− 1·31		+ 5·78	− 3·45	
9	o=+o·111					− 1·89	+ 8·06	− 5·78
10	o=+o·211	....	....	....	....	− 7·00	+14·25	−12·35
11	o=−o·276					+ 3·11	−15·72	+18·88
12	o=−o·622						− 4·08	− 0·56
13	o=+o·673				+ 0·76	+ 2·49	− 1·07	
14	o=+o·414							− 1·94
16	o=−o·522	....	....	....	....	− 0·68		
25	o=+1·573	+2·0						
27	o=−o·424	+4·0						
28	o=+4·93		+230·17	− 9·48	−115·30			
29	o=+1·83			+115·34	+ 1·46	−77·76	+ 3·38	
30	o=−3·59	....	....	....	+242·32	−23·97	....	....
31	o=+o.60					+194·71	−69·25	+24·89
32	o=+1·97						+310·66	−221·34
33	o=−1·66							+230·26

(*c*) *Figure adjustment*—Completed.

Normal equations—Completed.

		C_{34}	C_{35}	C_{36}	C_{37}	C_{38}	C_{39}	C_{40}
3	0=−0·295							−10·72
4	0=+1·084							−2·11
5	0=+0·101							+8·60
6	0=−0·059	+1·20						+7·55
7	0=−0·134	....	....	....	....	....	....	−2·58
8	0=−0·932	−2·15						
10	0=−0·211	+5·72						−0·80
11	0=−0·276	−4·70		−0·57				
12	0=−0·622	+1·72						
13	0=+0·673	−2·41	+7·63	....	....	....	....	+0·99
14	0=+0·414	+1·33	+14·25	+2·12				−1·69
15	0=−1·043	−2·64	−18·67	−4·43				+6·57
16	0=−0·522	+12·88	+8·01	+1·84				−14·04
17	0=+0·651	+0·26		+2·25				
18	0=−0·334	....	....	−5·30	....	....	....	−0·79
19	0=−1·324	+0·01	+0·01	+7·92				−7·94
20	0=+0·195			−4·12	+0·39			+5·40
21	0=−0·510			+0·69	−2·21			−2·33
22	0=+0·848				−2·18			+0·10
23	0= 1·557	....	....	....	+8·60	+4·54	....	....
24	0=+0·222				+4·05	+2·20	+5·79	+2·63
25	0=−1·573				−7·58	−6·95	+2·95	+2·95
26	0=−0·759				+2·36	+0·75	−8·74	+0·39
27	0=−0·424				+2·56	+5·56		
28	0=+4·93	....	....	....	....	....	....	+56·29
29	0=−1·83							+15·15
30	0=−3·59	+1·08						−3·76
31	0=+0·60	−3·33	+5·27					−75·97
32	0=+1·97	−15·00						+7·51
33	0=−1·66	−20·54	....	+3·29	....	....	....	......
34	0=+0·33	+126·96	+55·25	−10·00				−82·04
35	0=+8·55		+723·76	+12·72				−78·15
36	0=+1·22			+100·34	+2·53			−52·49
37	0=−3·72				+122·15	+47·39	−18·81	+28·00
38	0=−1·72	....	....	....	....	+76·90	−32·58	−32·58
39	0=−3·34						+449·50	+23·29
40	0=−8·55							+261·61

Resulting values of correlates.

$C_1=+0·226\ 6$	$C_{11}=+0·273\ 6$	$C_{21}=+0·123\ 8$	$C_{31}=+0·085\ 5$
$C_2=-0·223\ 8$	$C_{12}=+0·251\ 8$	$C_{22}=-0·088\ 3$	$C_{32}=+0·076\ 0$
$C_3=+0·532\ 8$	$C_{13}=+0·080\ 3$	$C_{23}=+0·141\ 7$	$C_{33}=+0·072\ 04$
$C_4=-0·044\ 6$	$C_{14}=+0·154\ 0$	$C_{24}=-0·047\ 7$	$C_{34}=+0·136\ 1$
$C_5=-0·031\ 7$	$C_{15}=+0·400\ 9$	$C_{25}=-0·300\ 5$	$C_{35}=-0·000\ 33$
$C_6=+0·134\ 3$	$C_{16}=+0·254\ 0$	$C_{26}=+0·038\ 3$	$C_{36}=+0·087\ 5$
$C_7=+0·218\ 1$	$C_{17}=-0·029\ 7$	$C_{27}=+0·155\ 0$	$C_{37}=-0·088\ 8$
$C_8=+0·263\ 8$	$C_{18}=+0·213\ 4$	$C_{28}=-0·051\ 0$	$C_{38}=+0·113\ 7$
$C_9=+0·148\ 5$	$C_{19}=+0·531\ 2$	$C_{29}=+0·084\ 3$	$C_{39}=+0·005\ 51$
$C_{10}=+0·129\ 1$	$C_{20}=+0·169\ 3$	$C_{30}=-0·020\ 74$	$C_{40}=+0·188\ 8$

Corrections to angular directions.

″	″	″	″
(1)=−0·229 3	(24)=−0·049 5	(47)=−0·004 9	(70)=−0·180 0
(2)=−0·057 5	(25)=+0·053 9	(48)=+0·087 5	(71)=+0·162 7
(3)=+0·322 9	(26)=−0·131 6	(49)=+0·333 7	(72)=+0·065 0
(4)=−0·018 4	(27)=−0·269 0	(50)=+0·021 7	(73)=−0·008 2
(5)=−0·142 1	(28)=+0·373 3	(51)=−0·243 1	(74)=−0·035 6
(6)=−0·246 6	(29)=−0·058 5	(52)=−0·244 1	(75)=−0·267 6
(7)=+0·422 1	(30)=+0·056 3	(53)=−0·046 6	(76)=+0·498 4
(8)=−0·247 3	(31)=−0·092 7	(54)=+0·155 1	(77)=−0·533 4
(9)=−0·041 0	(32)=−0·134 8	(55)=−0·014 0	(78)=+0·253 0
(10)=+0·375 3	(33)=+0·209 0	(56)=−0·225 0	(79)=+0·169 7
(11)=+0·200 1	(34)=−0·341 0	(57)=−0·299 8	(80)=−0·319 7
(12)=−0·247 6	(35)=+0·240 4	(58)=−0·219 3	(81)=+0·166 6
(13)=+0·215 7	(36)=+0·072 3	(59)=+0·605 1	(82)=+0·085 6
(14)=−0·082 3	(37)=+0·383 4	(60)=−0·156 6	(83)=+0·370 2
(15)=+0·023 6	(38)=−0·139 4	(61)=+0·266 8	(84)=−0·391 9
(16)=−0·333 0	(39)=−0·081 3	(62)=−0·109 4	(85)=−0·002 2
(17)=+0·067 9	(40)=−0·035 8	(63)=−0·258 8	(86)=+0·261 6
(18)=+0·066 3	(41)=−0·058 0	(64)=−0·033 2	(87)=+0·051 5
(19)=+0·053 6	(42)=−0·354 9	(65)=+0·161 4	(88)=−0·163 7
(20)=−0·009 7	(43)=+0·429 0	(66)=+0·084 3	(89)=+0·103 6
(21)=−0·175 9	(44)=−0·089 8	(67)=−0·004 5	(90)=+0·227 4
(22)=−0·018 1	(45)=−0·099 4	(68)=−0·162 5	(91)=+0·058 7
(23)=+0·196 3	(46)=+0·095 6	(69)=+0·135 6	

(d) Adjusted triangles, Utah, Nevada, and California.

No.	Stations	Observed angles. °	′	″	Corrections. ″	Spherical angles. ″	Spherical excess. ″	Log s.	Distances in metres.
	Mount Lola	28	49	08·348	−0·448	07·900	19·081	5·032 332 5	107 728·96
1	Mount Diablo	73	06	32·769	−0·229	32·540	19·081	5·330 156 4	213 873·23
	Mount Helena	78	05	16·661	+0·142	16·803	19·081	5·339 857 7	218 704·43
				57·778			57·243		
	Round Top	27	47	26·403	+0·106	26·509	17·047	5·032 332 5	107 728·96
2	Mount Diablo	97	32	05·482	−0·058	05·424	17·046	5·360 026 7	229 100·84
	Mount Helena	54	41	18·960	+0·247	19·207	17·047	5·275 465 4	188 566·86
				50·845			51·140		
	Round Top	96	40	15·471	−0·251	15·220	14·431	5·339 857 7	218 704·43
3	Mount Diablo	24	25	32·713	+0·172	32·885	14·432	4·959 228 2	91 039·14
	Mount Lola	58	54	55·365	−0·175	55·190	14·432	5·275 465 4	188 566·86
				43·549			43·295		
	Mount Lola	87	43	63·713	−0·623	63·090	16·466	5·360 026 7	229 100·84
4	Round Top	68	52	49·068	−0·357	48·711	16·466	5·330 156 4	213 873·21
	Mount Helena	23	23	57·701	−0·104	57·597	16·466	4·959 228 2	91 039·14
				50·482			49·398		
	Mocho	26	16	13·174	−0·166	13·008	2·145	4·779 637 7	60 205·71
5	Mount Tamalpais	23	47	55·965	+0·422	56·387	2·145	4·739 494 2	54 890·12
	Mount Diablo	129	55	57·021	+0·019	57·040	2·145	5·018 315 9	104 307·60
				6·160			6·435		
	Mocho	80	34	51·975	+0·158	52·133	8·691	5·275 465 4	188 566·86
6	Mount Diablo	82	43	67·395	+0·039	67·434	8·692	5·277 860 6	189 609·73
	Round Top	16	41	26·805	−0·298	26·507	8·691	4·739 494 1	54 890·11
				26·175			26·074		
	Mount Conness	54	14	19·252	−0·186	19·066	15·284	5·275 465 4	188 566·86
7	Mount Diablo	24	49	05·976	+0·380	06·356	15·284	4·989 137 4	97 529·81
	Round Top	100	57	20·565	−0·135	20·430	15·284	5·358 240 4	228 160·48
				45·793			45·852		
	Mount Conness	67	23	41·171	−0·082	41·089	15·575	5·277 860 6	189 609·73
8	Mocho	28	21	11·501	+0·214	11·715	15·575	4·989 137 4	97 529·81
	Round Top	84	15	53·760	+0·162	53·922	15·576	5·310 407 7	204 365·52
				46·432			46·726		
	Mocho	108	55	63·476	+0·372	63·848	8·982	5·358 240 4	228 160·48
9	Mount Diablo	57	54	61·419	−0·341	61·078	8·983	5·310 407 7	204 365·52
	Mount Conness	13	09	21·919	+0·103	22·022	8·983	4·739 494 1	54 890·11
				26·814			26·948		

(*d*) *Adjusted triangles, Utah, Nevada, and California*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
10	Mount Como	71	46	23·128	+0·115	23·243	4·359	4·959 228 2	91 039·14
	Round Top	69	01	21·198	+0·401	21·599	4·358	4·951 801 5	89 495·56
	Mount Lola	39	12	27·817	+0·416	28·233	4·358	4·782 386 2	60 587·94
				12·143			13·075		
11	Pah-Rah	62	37	05·836	−0·168	05·668	5·572	4·951 801 5	89 495·56
	Mount Como	58	59	38·087	−0·149	37·938	5·571	4·936 443 9	86 386·11
	Mount Lola	58	23	32·902	+0·206	33·108	5·571	4·933 671 6	85 836·42
				16·825			16·714		
12	Mount Grant	34	23	52·977	+0·058	53·035	3·927	4·782 386 2	60 587·94
	Round Top	46	21	05·874	−0·002	05·872	3·927	4·889 880 9	77 603·44
	Mount Como	99	15	13·142	−0·267	12·875	3·928	5·024 709 1	105 854·45
				11·993			11·782		
13	Mount Grant	26	21	30·009	+0·046	30·055	4·320	4·933 671 6	85 836·42
	Mount Como	129	58	45·643	+0·302	45·945	4·319	5·170 715 1	148 154·59
	Pah-Rah	23	39	....	....	56·959	4·320	4·889 880 9	77 603·44
							12·959		
14	Carson Sink	36	46	34·170	−0·091	34·079	7·663	4·889 880 9	77 603·44
	Mount Grant	72	36	09·537	+0·023	09·560	7·664	5·092 359 5	123 697·10
	Mount Como	70	37	39·007	+0·344	39·351	7·663	5·087 382 7	122 287·65
				22·714			22·990		
15	Carson Sink	42	43	59·074	+0·083	59·157	7·729	4·933 671 6	85 836·42
	Mount Como	59	20	66·636	−0·042	66·594	7·729	5·036 732 7	108 826·03
	Pah-Rah	77	55	16·856	+0·581	17·437	7·730	5·092 359 5	123 697·10
				22·566			23·188		
16	Pah-Rah	54	15	...	....	20·477	11·073	5·087 382 7	122 287·65
	Carson Sink	79	30	33·244	−0·008	33·236	11·073	5·170 715 1	148 154·59
	Mount Grant	46	14	39·528	−0·022	39·506	11·073	5·036 732 7	108 826·03
							33·219		
17	Mount Conness	71	52	51·927	−0·137	51·790	6·391	5·024 709 1	105 854·45
	Round Top	46	59	56·892	−0·013	56·879	6·390	4·910 909 9	81 453·53
	Mount Grant	61	07	31·025	−0·523	30·502	6·390	4·989 137 4	97 529·81
				19·844			19·171		
18	Toiyabe Dome	60	28	33·100	−0·312	32·788	10·680	5·087 382 7	122 287·65
	Mount Grant	53	27	24·722	−0·297	24·425	10·680	5·052 722 1	112 907·29
	Carson Sink	66	04	34·633	+0·195	34·828	10·681	5·108 779 9	128 463·56
				32·455			32·041		

(*d*) *Adjusted triangles, Utah, Nevada, and California*—Continued.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
19	Lone Mountain	69	16	41·720	+0·080	41·800	9·222	5·108 779 9	128 463·56
	Mount Grant	41	15	32·471	+0·784	33·255	9·222	4·957 002 6	90 573·82
	Toiyabe Dome	69	28	12·433	+0·179	12·612	9·223	5·109 327 4	128 625·60
				26·624			27·667		
20	Mount Conness	25	39	....	....	14·969	5·878	5·108 779 9	128 463·56
	Mount Grant	138	24	61·739	+0·738	62·477	5·879	5·294 365 5	196 954·33
	Toiyabe Dome	15	55	59·841	+0·348	60·189	5·878	4·910 909 9	81 453·53
							17·635		
21	Mount Conness	52	37	50·082	+0·642	50·724	8·799	5·109 327 4	128 625·60
	Mount Grant	97	09	29·268	−0·045	29·223	8·799	5·205 720 4	160 590·72
	Lone Mountain	30	12	66·525	−0·075	66·450	8·799	4·910 909 9	81 453·53
				25·875			26·397		
22	Mount Conness	26	58	....	....	35·755	12·143	4·957 002 6	90 573·82
	Toiyabe Dome	53	32	12·592	−0·169	12·423	12·143	5·205 720 4	160 590·70
	Lone Mountain	99	29	48·245	−0·006	48·251	12·143	5·294 365 5	196 954·33
							36·429		
23	Mount Callahan	63	24	23·340	0·376	22·964	8·691	5·052 722 1	112 907·29
	Toiyabe Dome	61	40	31·378	−0·265	31·113	8·690	5·045 902 0	111 148·09
	Carson Sink	54	55	32·004	0·010	31·994	8·690	5·014 250 6	103 335·74
				26·722			26·071		
24	Diamond Peak	40	10	67·703	−0·089	67·614	8·394	5·014 250 6	103 335·74
	Toiyabe Dome	37	47	57·643	−0·001	57·642	8·394	4·991 899 7	98 152·13
	Mount Callahan	102	01	19·503	−0·424	19·927	8·395	5·194 906 6	156 641·41
				24·849			25·183		
25	White Pine	30	02	13·686	+0·298	13·984	12·874	4·957 002 6	90 573·82
	Lone Mountain	70	58	21·456	−0·824	22·280	12·874	5·233 181 1	171 072·83
	Toiyabe Dome	78	59	62·155	+0·202	62·357	12·873	5·249 533 5	177 637·04
				37·297			38·621		
26	Diamond Peak	69	25	33·644	−0·077	33·567	17·767	5·233 181 1	171 072·83
	White Pine	59	00	36·559	−0·316	36·243	17·766	5·194 906 6	156 641·40
	Toiyabe Dome	51	34	43·291	+0·198	43·489	17·766	5·155 806 4	143 154·98
				53·494			53·299		
27	Wheeler Peak	62	48	33·104	−0·028	33·076	13·962	5·155 806 4	143 154·98
	White Pine	65	00	37·554	+0·343	37·897	13·961	5·163 979 8	145 874·65
	Diamond Peak	52	11	30·717	+0·195	30·912	13·962	5·104 322 6	127 151·82
				41·375			41·885		

(*d*) *Adjusted triangles, Utah, Nevada, and California*—Completed.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
28	Pioche	61	45	62·433	−0·489	61·944	11·183	5·104 322 6	127 151·82
	White Pine	51	43	37·675	−0·098	37·577	11·183	5·054 232 6	113 300·72
	Wheeler Peak	66	30	54·288	−0·261	54·027	11·182	5·121 780 1	132 367·11
				34·396			33·548		
29	Tushar	39	24	53·610	+0·285	53·895	14·398	5·054 232 6	113 300·72
	Pioche	82	32	20·600	+0·486	21·086	14·399	5·247 845 6	176 948·00
	Wheeler Peak	58	03	27·428	+0·786	28·214	14·398	5·180 217 3	151 431·85
				41·638			43·195		
30	Ibepah	61	06	60·345	−0·215	60·130	12·168	5·163 979 8	145 874·65
	Wheeler Peak	82	13	17·832	−0·232	17·600	12·168	5·217 667 5	165 069·75
	Diamond Peak	36	40	18·549	+0·225	18·774	12·168	4·997 793 9	99 493·31
				36·726			36·504		
31	Ibepah	60	21	30·668	−0·210	30·458	14·898	5·247 845 6	176 948·00
	Tushar	29	15	27·917	0·762	27·155	14·898	4·997 793 9	99 493·31
	Wheeler Peak	90	23	47·348	−0·266	47·082	14·899	5·308 765 3	203 594·16
				45·933			44·695		
32	Mount Nebo	48	03	65·671	−0·169	65·502	24·586	5·247 845 6	176 948·00
	Tushar	88	16	31·284	−0·372	30·912	24·587	5·376 155 4	237 769·09
	Wheeler Peak	43	40	38·377	−1·032	37·345	24·586	5·215 521 5	164 256·13
				75·332			73·759		
33	Mount Nebo	23	07	63·497	−0·059	63·438	14·572	4·997 793 9	99 493·31
	Wheeler Peak	46	42	68·971	+0·766	69·737	14·572	5·265 702 7	184 375·27
	Ibepah	10	09	30·489	−0·052	30·541	14·572	5·376 155 4	237 769·08
				42·957			43·716		
34	Mount Nebo	71	12	09·168	−0·227	08·941	24·260	5·308 765 3	203 594·16
	Tushar	59	00	63·367	+0·390	63·757	24·260	5·265 702 7	184 375·27
	Ibepah	49	47	59·821	+0·261	60·082	24·260	5·215 521 5	164 256·13
				72·356			72·780		
35	Pilot Peak	61	30	45·445	−0·104	45·549	40·118	5·376 155 4	237 769·08
	Mount Nebo	56	59	86·980	−0·059	86·921	40·118	5·355 824 1	226 894·59
	Wheeler Peak	61	30	....	....	47·885	40·119	5·376 158 1	237 770·57
							120·355		
36	Ibepah	154	12	35·600	−0·052	35·548	4·876	5·355 824 1	226 894·59
	Wheeler Peak	14	47	....	....	38·150	4·877	5·124 323 4	133 144·58
	Pilot Peak	10	59	60·828	+0·104	60·932	4·877	4·997 793 9	99 493·31
							14·630		

(e) Precision of the adjusted triangulation.

For a close estimate of the precision of the Nevada series of triangles, we find first the mean error of an angle resulting from the adjustment by the expression—$m = \sqrt{\frac{2\,[pvv]}{c}}$, in which p may be taken as unity. Then $[vv] = 4{\cdot}37$, $c = 40$, and $m = \pm 0''{\cdot}47$. The probable error in length of any line of the series due to the angular measures is found by the usual formulæ—

$$u_{a_n} = \tfrac{2}{3}\,(\delta_{a_n})^{-2} \sum_{a_1}^{a_n} [\delta_A^2 - \delta_A\delta_B - \delta_B^2] \quad \text{and} \quad e_{a_n} = 0{\cdot}674\,5m\sqrt{u_{a_n}}$$

We will compute the probable error in length of the line Tioyabe Dome-Lone Mountain, which is about midway between the two base nets. Starting from the side Ibepah-Mount Nebo, of the Salt Lake Base Net, we have $\delta_{a_n} = 4{\cdot}8$, $\Sigma = 74{\cdot}6$ (5 triangles), $e_{a_n} = \pm 0{\cdot}463$ metre, $e_b = \pm 0{\cdot}329$ metre, and $e_1 = \pm 0{\cdot}568$ metre. Starting from the side, Mount Helena to Mount Diablo, of the Yolo Base Net, we have $\Sigma = 92{\cdot}0$ (5 triangles), $e_{a_n} = \pm 0{\cdot}514$ metre, $e_b = \pm 0{\cdot}248$ metre, and $e_2 = \pm 0{\cdot}571$ metre. Then $e = \frac{e_1 e_2}{\sqrt{e_1^2 + e_2^2}} = \pm 0{\cdot}403$ metre, which is about $\frac{1}{226000}$ part of the length.

For the effect on the developed length of the arc, the distances being taken between the middle points of the terminal lines projected on the thirty-ninth parallel, we have approximately tne following values:

Terminal lines.	Distance.	Probable errors.	Average.	
	km.			*m.*
Ibepah to Mount Nebo and Toiyabe Dome to Lone Mountain	397·0	$\frac{1}{273000}$ and $\frac{1}{225000}$	$\frac{1}{248000}$	±1·60
Toiyabe Dome to Lone Mountain and Mount Diablo to Mount Helena	420·1	$\frac{1}{223000}$ and $\frac{1}{365000}$	$\frac{1}{278000}$	±1·51
	817·1			±3·11

(f) Description of stations situated between the base nets.

Mocho, Santa Clara County, California; established in 1875 by W. Eimbeck. This station is situated on the summit of the highest peak of the group of mountains lying to the eastward of Santa Clara Valley, on the eastern flank of the Mount Diablo Range and overlooks the San Joaquin Valley. It is about 11½ miles northeast from the Lick Observatory on Mount Hamilton and about 30 miles southeast of the town of Livermore, and is reached by wagon and pack animals over a rough road.

The geodetic point was marked in 1879 by a copper bolt sunk in the rock, over which, in 1887, was built a concrete pier 45 inches high by 24 inches square, enlarged at the top to 26 inches, to receive the theodolite.

The geodetic point was transferred to the top of the pier.

Round Top, Alpine County, California; established in 1876 by W. Eimbeck. This station is situated on a peak, on the crest of the Sierra Nevada Range of mountains, popularly known as Round Top. It is the highest and most easterly pinnacle, about 1 mile south of Carson Pass or the main summit of the Amador Grade. It can be

reached via Carson City, thence by stage via Genoa to Woodfords, 32 miles distant, thence by wagon or horseback up Hope Valley to the summit of the Amador Grade. The ascent to the top of the peak must be from the west or northwest.

The geodetic point is marked by a copper bolt five-eighths inch in diameter, set in a drill hole in the rock. Above this was built a pier of rough stone masonry for the theodolite to stand on. Three other piers were built for different instruments—one a little east of north and the other two nearly west of the geodetic point, and all were left standing to serve as reference marks.

No difficulty was experienced in finding the point when it was visited in 1893.

Mount Lola, Nevada County, California; established in 1876 by W. Eimbeck. This station is situated on the southernmost summit of the high ridge between Weber and Independence lakes and the town of Meadow Lake. Independence Lake lies at the southeast base of this ridge and Browns Valley is on the opposite side. The station is about 25 feet northwest from the highest part of the mountain. It can best be reached from Truckee by stage or private conveyance 15 miles to Jansen's Hotel at the east end of Independence Lake, from whence it is about a three hours' ride up the eastern slope of the mountain to the station.

The geodetic point is marked by a cross cut on the top of a five-eighths inch copper bolt set in a heavy capstone firmly embedded in a rough stone pier laid in cement. This capstone is about 15 inches above the natural surface of the ground and 3 feet 9 inches above the base of the pier. The pier was then built higher and surmounted with another capstone 24 inches square with a hole drilled through it, marking the point. The pier was surrounded by a stone wall, about 6 feet distant, to serve as a wind-break. Three brick piers on stone foundations—one north 36°·5 east, distant 27 feet 9½ inches; one north 44°·8 east, distant 31 feet 3 inches, and the other north 27°·75 west—were left standing as reference marks.

No difficulty was experienced in finding the point when visited in 1893.

Mount Conness, Tuolumne County, California; established in 1879 by L. A. Sengteller. Mount Conness is a lofty peak of the Sierra Nevada Range, about 25 miles a little east of north from the Yosemite Valley, about 10 miles north of Soda Springs in the Tuolumne Meadows, and about 30 miles southwest of the California and Nevada boundary. The station is located on the highest pinnacle of the summit, which is a very small irregular crag. The sheer descent around four-fifths of the summit is over 1 000 feet to the talus.

The geodetic point is marked by a cross cut on top of a copper bolt, five-eighths inch in diameter by 6 inches long, projecting 3½ inches above the solid rock. Above this was built a solid concrete pier 26 inches in diameter and about 40 inches high. On its upper surface was embedded a copper bolt five-eighths inch in diameter by 4 inches long, having a broad spherical head with a small silver pin in the center. A cross cut on the head of the bolt, a little to one side of the silver pin, marks the geodetic point.

Pah-Rah, Washoe County, Nevada; established in 1874 by W. Eimbeck. This station is situated on the northernmost of the three principal summits of the Virginia Mountains, the middle one, about 3 miles south, being the highest.

It lies just south of Pyramid Lake in the great bend of the Truckee River and is visible from both Reno and Wadsworth, two towns on the Central Pacific Railroad bearing north 44° east, distant 26 miles from Reno, and north 44° west, distant 12 miles

from Wadsworth. It may be reached from either place by road and trail—35 miles from the former and 20 miles from the latter place.

The geodetic point is marked by a half-inch copper bolt cemented into the bed rock as a subsurface mark, over which a stone slab, with a three-fourths-inch drill hole in the center, was firmly cemented in position as a surface mark. Around the station was built, to serve as a wind-break, a rough stone circular wall, of about 8 feet interior diameter, with an opening to the northeast.

A stone pier, bearing north 37°·26 east and distant 8·5 feet from the geodetic point, was left standing as a reference mark.

Mount Como, Douglas County, Nevada; established in 1879 by W. Eimbeck. This station is situated on a sharp conical peak of the Como Range of mountains lying between Carson and Mason valleys, about 20 miles nearly due east from the town of Genoa, about 20 miles southeast from Carson City, and about 17 miles south-southeast from Dayton. It may be reached from either Carson City or Dayton by wagon road, distant about 30 miles. The geodetic point is marked as follows: The subsurface mark is a half-inch by 4-inch copper bolt leaded into a large and well-bedded granite rock. The surface mark is a half-inch drill hole in the center of a large flat stone, 19 by 22 inches square and 5 inches thick, firmly cemented to the top of a stone and brick pier built over and around the lower mark to a height of 9 inches above the bolt. A ring wall of stone, resembling the figure 6, built to serve as a wind-break, was left standing. Lieutenant Wheeler's monument, about 35° west of south and 10 feet distant from the geodetic point, forms part of the wall. Two piers, one north and one south, were left standing as reference marks. Drill holes were made in the rock; one in line to Round Top, distant 6·25 metres; one in line to north pier, distant 10·6 metres, and one in line to south pier, distant 7·24 metres, from the geodetic point. Angle at the center between south pier and Round Top is 71° 01′ and between Round Top and north pier is 129° 51′.

Mount Grant, Esmeralda County, Nevada; established in 1878 by A. F. Rodgers. This station is on a high peak of the Wassuck Range, about 7 or 8 miles west of the southern end of Walker Lake. The mountain can be easily recognized by its three sharp peaks, one of which, King Peak, stands high above the others. The station is on the central peak about 200 metres north of King Peak. The nearest railroad station is (1882) Hawthorne, just south of Walker Lake, on the Centralia and Chester Railroad, distant about 10 miles from the mountain.

The geodetic point is marked by a copper bolt sunk in a rock embedded in a stone and brick foundation pier, the top of which extends about 8 inches above the bolt with a center pit in which a notice of approximate height and geographic position was embedded in cement. A stone ring wall 15·5 feet interior diameter, with a long wing projecting to the southward and curving around the vertical circle pier (distant 32·5 feet from the center), was left standing.

The wall and piers will serve as good reference marks for identifying the station.

Carson Sink, Churchill County, Nevada; established in 1878 by W. Eimbeck. This station is located on the highest point of a prominent and well-known peak of the Carson Sink Range, about 20 miles in an easterly direction from Stillwater, the county seat of Churchill County. The nearest railroad station is (1880) Wadsworth, on the Central Pacific Railroad, distant about 70 miles in a westerly direction. The peak has a gradual eastern and precipitous western slope.

The geodetic point is marked by a half-inch by 4-inch copper bolt set in solid rock

at the center of the foundation pier for theodolite. At the close of observations a large, light, porous rock was sawed to fit closely on top of the pier and the center marked by a drill hole. The entire pier was then covered with small rocks set in cement. The astronomical pier, distant 74·49 feet northeasterly, and the vertical circle pier, distant 26·67 feet southwesterly, from the geodetic point, were left standing. Additional reference marks are four three-fourths inch drill holes in the solid rock—one distant 10·24 feet nearly north, one distant 17·59 feet about east-northeast, one distant 17·65 feet about south-southeast, and one 6·53 feet nearly west, from the geodetic point. The stone ring walls (wind-breaks) partially surrounding the central and vertical piers were also left standing.

Toiyabe Dome, Nye County, Nevada; established in 1878 by A. F. Rodgers. This station is located on the highest and boldest peak at the southern extremity of the Toiyabe Range, steep on the western and very abrupt on the eastern slope. The top of the mountain is covered with a mass of loose rocks lying on the solid ledge. The geodetic point is marked by a half-inch copper bolt set in the solid rock, around and over which was built the usual stone and brick foundation pier for the theodolite, in the central pit of which was imbedded in cement a tin can containing the approximate altitude and geographic position. Around the station was built a stone wall, 12 feet interior diameter, with an opening on the northwest side. The vertical circle pier, bearing north 28° 47′ west, distant 141·42 feet from the geodetic point and surrounded by a ring wall, 10 feet interior diameter, with an opening on the southeast side, and the astronomical pier, nearly in line and about half way between the two other piers, were left standing. Additional reference marks are 4 drill holes—one bearing north 44° 44′ west, distant 15·42 feet; one bearing north 78° 19′ east, distant 16·83 feet; one bearing south 51° 53′ east, distant 8·14 feet, and one bearing south 26° 14′ west, distant 18·4 feet, from the geodetic point.

Lone Mountain, Esmeralda County, Nevada; established in 1878 by A. F. Rodgers. This station is located on a prominent peak, well known in the surrounding section, situated in a dry desert country, about 60 miles, by road, in a southerly direction from Cloverdale and about 40 miles in an easterly direction from Columbus. The nearly extinct mining camps of Silver Peak and Montezuma lie about 25 miles in a southwesterly and southeasterly direction respectively from the mountain.

The geodetic point is marked by a cross on a half-inch copper bolt leaded in a drill hole in a solid ledge of slate dipping westward, around which was built the usual stone and brick foundation pier for the theodolite, surrounded by a stone ring wall 15·5 feet in diameter, with an opening to the northeast. The vertical circle pier, distant 71·1 feet about northeast from the geodetic point, and surrounded by a stone ring wall 10·7 feet in diameter, opening to the northeast, was left standing. Additional reference marks are four drill holes—one about north, distant 9·15 feet; one about north-northeast, distant 13·78 feet; one about south-southeast, distant 21·59 feet; and one a little north of west, distant 8·2 feet, from the geodetic point.

Mount Callahan, Lander County, Nevada; established in 1879 by W. Eimbeck. This station is located on the highest point of a broad flat ridge on the summit of a large flat-top mountain at the northern extremity of the Toiyabe Range, about 20 miles north of Austin, the present (1881) terminus of the Nevada Central Railroad. The mountain is accessible from all sides. The geodetic point is marked by a five-eighths by 4 inch copper bolt, set in plaster of Paris in a large rock bedded in cemented grout,

and forming the center of the usual rock foundation pier for the theodolite. A bottle, containing the approximate latitude and longitude, was set in plaster of Paris in the central pit of the pier, and the whole covered with a large rock having drill hole over the bolt, as a surface mark. Reference marks are three drill holes in solid rocks—one due north, distant 11·42 feet; one north 120° east, distant 12.17 feet; and one north 120° west, distant 11·09 feet, from geodetic point. Also the magnetic station pier, north 14° 12′ east, distant 61·02 feet; the astronomical pier, north 68° 12′ east, distant 113 feet; and the vertical circle pier, south 4° 10′ west, distant 37·83 feet, from geodetic point. The usual circular stone ring walls around the central and vertical circle piers and an L-shaped wall at the magnetic station were left standing.

Diamond Peak, Eureka County, Nevada; established in 1879 by W. Eimbeck. This station is located upon the highest point of the Diamond Range of mountains, about 12 miles northeast of the mining town of Eureka, the present (1881) terminus of the Eureka and Palisade Railroad. The peak is well known throughout the surrounding country.

The station is on a small cone rising from a small approximately level space on the south end of the ridge. The geodetic point is marked by a five-eighths by 4 inch copper bolt set in a solid rock in the center of the stone foundation pier for the theodolite. Reference marks are four drill holes—one about north-northeast, distant 10·73 feet; one about east-southeast, distant 15·49 feet; one nearly south, distant 8·69 feet, and one nearly west, distant 9·32 feet; the astronomical pier, about east-northeast, distant 84·81 feet, and the vertical circle pier a little east of south, distant 77·59 feet, from the geodetic point. The usual circular stone ring walls surrounding the central and vertical circle piers were left standing.

White Pine, Nye County, Nevada; established in 1879 by W. Eimbeck. This station is located on the highest and boldest point of the White Pine Range of mountains, called on Lieutenant Wheeler's map the Grant Range. The local name of the point is Troy Peak. The station is near the edge of a precipice; the rocky bluff, at a distance of a few feet, falling almost vertically for seven or eight hundred feet. The geodetic point is marked by a five-eighths by 4 inch copper bolt set in solid rock in the center of the stone foundation pier for the theodolite. A bottle, containing the approximate height and geographical position of the station, was embedded in plaster of Paris in the central pit of the pier, above the bolt. The reference marks are three drill holes—one about northeast, distant 10·3 feet; one about south-southeast, distant 7·65 feet, and one about northwest, distant 9 feet, from the geodetic point. The vertical circle station is 27·62 feet distant from the geodetic station in a northeasterly direction.

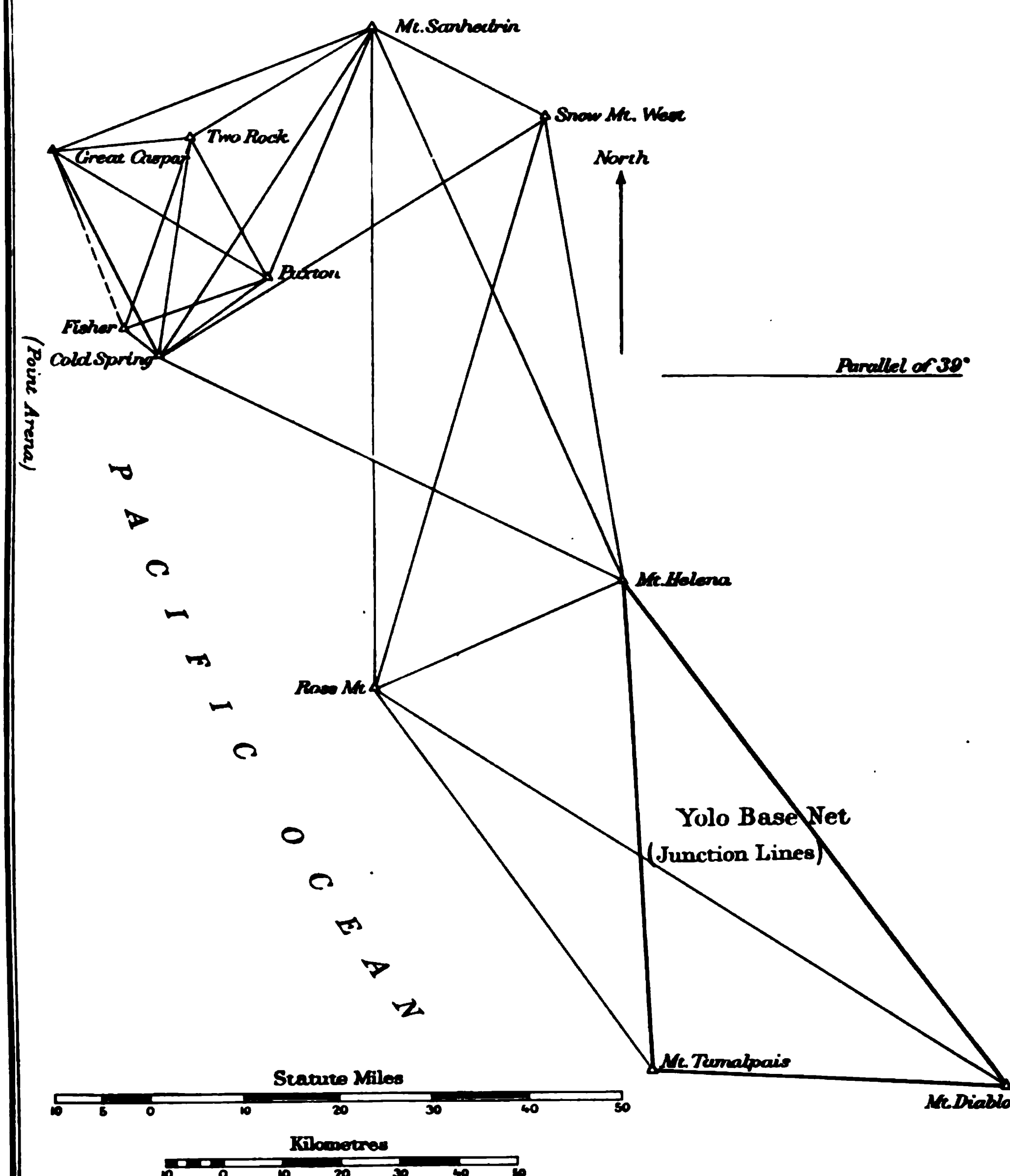
The usual circular stone ring walls surrounding the central and the vertical circle stations, the two stone cabins used for living purposes, and the bolts and drills, to which the guy ropes of observing tents were fastened, were left in position.

Wheeler Peak, White Pine County, Nevada; established in 1878 by A. F. Rodgers. This peak, locally known as Jeff Davis Peak, is by far the most prominent of the Snake Range and is widely known all over the States of Nevada and Utah. The range is flanked on the west by Spring Valley and on the east by Snake Valley, from either of which the peak is accessible. The geodetic point is situated on the western or highest prong of the double peak and is marked as a subsurface mark in the usual way by a half-inch copper bolt set in solid rock in the center of the foundation pier for the theodolite. The pier is covered by a stone slab having a three-fourths-inch drill hole in

YOLO BASE NET TO PACIFIC COAST

WESTERN OR COAST RANGE SERIES

CALIFORNIA



its center, securely cemented in the top as a surface mark. The vertical circle station was located to the eastward of the geodetic point, distant 173·06 feet, and both points were surrounded with circular stone walls, which were left standing. Reference marks are three drill holes—one north, distant 8·17 feet; one in a southeast direction, distant 8·53 feet, and one in a southwest direction, distant 7·87 feet, from the geodetic point.

Pioche, Lincoln County, Nevada; established in 1879 by W. Eimbeck. This station is located on the highest rock knoll of a peak in the mountains just east of Eagle Valley. The peak is about 1 000 feet west of the boundary line between the States of Nevada and Utah, and bears north 80° 25′ east, distant 22·5 miles (about 33 miles by road), from the court-house in the town of Pioche. The geodetic point is marked by a half-inch copper bolt leaded into the solid rock in the center of the stone foundation pier for the theodolite, as a subsurface mark. The pier is covered by a stone slab, having a three-fourths-inch drill hole in its center, securely cemented to its top, as a surface mark. The copper bolt is 8¾ inches below the top of the drill hole. The vertical circle station bears north 26° 20′·8 east, distant 69·23 feet, from the geodetic point, and both points were surrounded with circular stone walls, which were left standing.

Reference marks are five drill holes—one north 34° 28′ east, distant 8·27 feet; one south 88° 22′ east, distant 7·91 feet; one south 15° 14′ east, distant 8·92 feet; one north 88° west, distant 7·71 feet; and one north 28° 57′ west, distant 6·56 feet, from the geodetic point.

Tushar, Piute County, Nevada; established in 1882 by W. Eimbeck. This station is located on the summit of the most northern of the highest three peaks in the Tushar Range, the backbone of which forms the boundary between Piute and Beaver counties, locally known as Mount Belknap. It can be reached easiest from Marysvale, a small village situated on the Upper Sevier River, about 10 miles distant in an air line to the eastward from the peak. The geodetic point is marked by a five-eighths-inch copper bolt leaded into the solid rock, around and over which was built the stone foundation pier for the theodolite, with a stone slab, having a drill hole in its center, securely cemented on its top. The top of the copper bolt is 11¼ inches below the drill hole in the slab.

The vertical circle station is almost due north, distant 34·12 feet, from the geodetic point. The circular stone walls around these stations were left standing. The one around the geodetic point, 11 feet interior diameter, with wall 2·5 feet thick and 4·5 feet high, built in a very solid manner and concentric with the station bolt, makes an excellent reference mark in the absence of the usual drill holes, owing to the shattered and loose condition of the shale rocks about the station.

II. THE WESTERN OR COAST RANGE SERIES OF TRIANGLES, 1878 TO 1892.

(*a*) *Introduction.*

This triangulation runs parallel with the coast, covering the region between San Francisco and Point Arena, which is near the western termination of the arc and in the same latitude as its eastern end. The southern portion of this region had become known before the year 1856, and further reconnaissances were made by Assistants W. Eimbeck and C. Rockwell during 1874–1877. The trend of the principal range of mountains is parallel with the coast, and its crest at Snow Mountain West reaches an

altitude of 2 146 metres, or nearly 7 040 feet, but the range lying between it and the coast is at a much lower level, and the highest points probably do not reach half of the above height.

This triangulation was not pursued steadily, and there were a number of observers engaged upon it in part during the period 1876–1880 and again in 1891 and 1892. As a result, the different methods employed do not admit of a general description. At the five stations lying west of the line Ross Mountain to Mount Sanhedrin repeating theodolites were employed, and the accuracy of the results at these subordinate stations does not come up to that obtained at the main stations. It may be noted here that at one of these stations (Great Caspar) the 30-centimetre (12-inch) theodolite was mounted on the top of a quadrangular scaffold 13 stories high, and stood 41·14 metres (or 135 feet) above ground, while the observer was independently supported by a central redwood tree with a two-story superstructure built over its top. (See illustration.)

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment.*

Mount Diablo, Contra Costa County, California. June 25 to September 8, 1876. 50-centimetre theodolite, No. 5. G. Davidson, C. Rockwell, and W. Eimbeck, observers. November 14 to December 29, 1884. 50-centimetre theodolite, No. 115. R. A. Marr, observer. (G. Davidson, chief of party.) June 28 to July 19, 1892. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and first figure adjustment.	Corrections from base-net, first, and second figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″	″
	Mount Helena	0	00	00·000	−0·082	59·918	−0·645	....	....	59·273
	Monticello	20	03	30·643	−0·032	30·611	−0·102	....	....	30·509
	Vaca	20	19	59·505	−0·024	59·481	+0·319	....	....	59·800
	Azimuth Mark (Clayton)	25	49	17·204	−0·010	17·194	....	....	....	....
	Yolo Northwest Base	38	39	09·129	0·000	09·129	+0·086	....	....	09·215
	Marysville Butte	38	40	30·881	+0·005	30·886	....	....	....	....
	Yolo Southeast Base	43	24	20·921	0·000	20·921	+0·524	....	....	21·445
	Mount Lola	73	06	31·834	+0·185	32·019	....	−0·206	....	31·813
	Pine Hill	76	14	00·524	+0·043	00·567	....	....	....	....
	Round Top	97	32	04·551	+0·181	04·732	....	−0·035	....	04·697
	Mount Conness	122	21	10·679	+0·029	10·708	....	+0·345	....	11·053
	Mocho	180	16	12·207	−0·080	12·127	....	+0·004	....	12·131
	Loma Prieta	211	22	06·404	−0·011	06·393	....	....	....	....
	Sierra Morena	249	16	39·858	+0·046	39·904	....	....	....	....
	Mount Tamalpais	310	12	09·226	−0·008	09·218	−0·047	....	....	09·171
1	Ross Mountain	339	08	13·637	−0·042	13·595	....	....	+0·755	14·350
							Mean	+0·024		

Probable error of a single observation of a direction (*D.* and *R.*) = $\pm 0''\cdot 72$.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Mount Tamalpais, Marin County, California. August 24 to October 9, 1882. 50-centimetre theodolite, No. 115. G. Davidson, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and first figure adjustment.	Corrections from base-net, first, and second figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″	″
	Mount Diablo	0	00	00·000	−0·011	$\overline{59·989}$	+0·277	....	....	00·266
	Mocho	23	47	56·302	−0·071	56·231	....	+0·422	....	56·653
	Sierra Morena	61	37	29·923	−0·037	29·886	....	....	....	....
2	Ross Mountain	230	31	28·940	−0·043	28·897	....	....	−0·266	28·631
	Mount Helena	263	31	35·075	−0·006	35·069	+0·054	....	....	35·123
	Monticello	289	01	42·852	+0·045	42·897	+0·048	....	....	42·945
	Vaca	307	25	02·177	+0·048	02·225	−0·380	....	....	01·845
							Mean	+0·084		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·54.

Mount Helena, Napa County, California. September 23 to November 26, 1876. 50-centimetre theodolite, No. 5. G. Davidson and W. Eimbeck, observers. August 14 to August 21, 1891. 50-centimetre theodolite, No. 115. E. F. Dickins, observer.

No. of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from base-net adjustment.	Corrections from base-net and first figure adjustment.	Corrections from base-net, first, and second figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″	″	″
	Mount Diablo	0	00	00·000	−0·073	$\overline{59·927}$	+0·183	....	....	00·110
	Mount Tamalpais	33	43	57·142	−0·004	57·138	+0·303	....	....	57·441
3	Ross Mountain	102	52	47·356	+0·032	47·388	....	....	−0·551	46·837
4	Cold Spring	153	08	42·324	−0·045	42·279	....	....	+0·268	42·547
5	Mount Sanhedrin	193	02	53·251	−0·089	53·162	....	....	+0·139	53·301
6	Snow Mountain West	208	09	11·511	−0·038	11·473	....	....	−0·322	11·151
	Snow Mountain East	208	37	44·912	....	....	....	....	....	....
	Azimuth Mark (Woods)	225	16	49·643	+0·007	49·650	....	....	....	....
	Marysville Butte	265	31	14·523	+0·042	14·565	....	....	....	....
	Mount Lola	281	54	43·341	+0·140	43·481	....	−0·174	....	43·307
	Pine Hill	303	14	10·280	+0·004	10·284	....	....	....	....
	Round Top	305	18	41·177	+0·005	41·182	....	−0·279	....	40·903
	Monticello	306	46	16·071	−0·002	16·069	+0·008	....	....	16·077
	Vaca	340	03	44·142	−0·045	44·097	−0·621	....	....	43·476
							Mean	−0·097		

Probable error of a single observation of a direction (*D.* and *R.*) = ±0″·62.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Continued.

Ross Mountain, Sonoma County, California.* July 4 to July 18, 1891. 50-centimetre theodolite, No. 115.† E. F. Dickins, observer.

Number of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
9	Mount Helena	0	00	00·000	+0·063	00·063	+0·345	00·408
	Santa Rosa court-house dome	34	49	14·835	....	....	....	....
10	Mount Diablo	56	15	40·940	−0·071	40·869	+0·190	41·059
11	Mount Tamalpais	77	51	13·776	−0·049	13·727	−0·142	13·585
7	Mount Sanhedrin	294	26	34·671	+0·004	34·675	−0·032	34·643
8	Snow Mountain West	311	13	18·000	+0·082	18·082	−0·361	17·721

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·77.

Snow Mountain West, Colusa County, California. June 2 to June 11, 1892. 50-centimetre theodolite, No. 115. E. F. Dickins, observer.

		°	′	″	″	″	″	″
	Snow Mountain East	0	00	00·00	....	....	....	....
12	Mount Helena	134	02	02·71	−0·02	02·69	+0·72	03·41
13	Ross Mountain	159	59	05·11	+0·03	05·14	+0·24	05·38
14	Cold Spring	201	21	47·76	+0·05	47·81	−0·43	47·38
15	Mount Sanhedrin	260	00	41·78	−0·10	41·68	−0·53	41·15

Probable error of a single observation of a direction (*D.* and *R.*) = ± 0″·90.

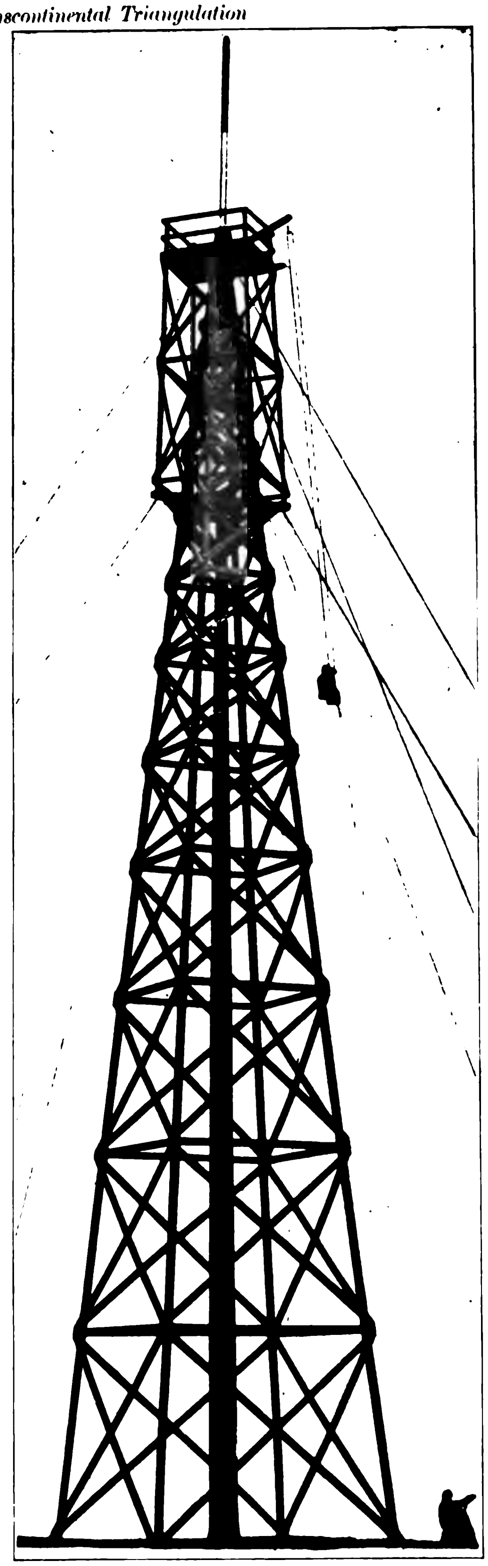
Mount Sanhedrin, Mendocino County, California. September 1 to October 15, 1880. 45-centimetre theodolite, No. 4. A. F. Rodgers, observer. September 17 to September 25, 1891. 50-centimetre theodolite, No. 115. E. F. Dickins, observer.

		°	′	″	″	″	″	″
	Reference Mark	0	00	00·00	....	....	....	....
17	Mount Helena	26	45	32·89	−0·06	32·83	−1·00	31·83
18	Ross Mountain	51	02	11·41	0·00	11·41	+0·15	11·56
	Ukiah court-house dome	63	23	15·19	....	....	....	....
19	Paxton	73	54	03·12	+0·05	03·17	−0·17	03·00
20	Cold Spring	84	01	14·48	+0·05	14·53	+0·02	14·55
21	Two Rock	110	28	13·94	+0·05	13·99	+0·19	14·18
22	Great Caspar	120	19	54·73	+0·01	54·74	+0·10	54·84
	Cahto	164	40	04·54	....	....	....	....
	King Peak	179	16	07·04	....	....	....	....
	Mount Lassic	206	47	46·02	....	....	....	....
16	Snow Mountain West	347	50	21·46	−0·12	21·34	+0·72	22·06

Probable error of a single observation of a direction (*D.* and *R.*) = ± 1″·11 in 1880
and (*D.* and *R.*) = ± 0″·74 in 1891.

* The station was established in 1855 by Assistant R. D. Cutts, and was occupied in 1859 and in 1860 by Assistant G. Davidson; these early observations have no direct relation to the present adjustment.

† Theodolite used in 17 positions with 2 series in each.



THE GREAT CASPAR SIGNAL, CALIFORNIA

Instrument mounted on main scaffolding at a height above ground of 41.1 meters or 135 feet. Observer supported independently by the central tree trunk and small top scaffolds surmounting it.

(*b*) ***Abstract of resulting horizontal directions at each station from local and from figure adjustment***—Continued.

Cold Spring, Mendocino County, California. September 27 to October 13, 1878. 30-centimetre theodolite, No. 37. B. A. Colonna and E. F. Dickins, observers. October 25 to November 6, 1891. 50-centimetre theodolite, No. 115. E. F. Dickins, observer.

Number of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
24	Great Caspar	0	00	00·00	−0·02	59·98	−0·90	59·08
25	Two Rock	35	40	27·72	+0·02	27·74	−0·11	27·63
26	Mount Sanhedrin	59	27	06·62	+0·11	06·73	+0·30	07·03
27	Paxton	80	58	04·52	+0·06	04·58	+0·12	04·70
28	Snow Mountain West	84	37	26·03	+0·13	26·16	+0·08	26·24
	Sanel Mountain	132	46	04·23	....	....	....	....
29	Mount Helena	142	17	28·22	−0·07	28·15	−0·20	27·95
	Walalla	198	56	26·21	....	....	....	....
	Clark	277	03	22·75	....	....	....	....
	Dunn	288	50	44·79	....	....	....	....
23	Fisher	336	58	41·18	−0·05	41·13	+0·70	41·83

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) = ± 0″·91 in 1878
and (*D.* and *R.*) = ± 0″·60 in 1891.

Great Caspar, Mendocino County, California. October 24 to November 29, 1878. 30-centimetre theodolite, No. 37. B. A. Colonna and J. F. Pratt, observers. August 30 to October 3, 1879. 30-centimetre theodolite, No. 37. A. F. Rodgers and D. B. Wainwright, observers. Telescope above ground 41·14 metres.

Number of direction.	Objects observed.	°	′	″	″	″	″	″
	King Peak	0	00	00·00	....	....	....	....
	Chemise Mountain	2	48	39·51	....	....	....	....
	Cahto	38	18	05·97	....	....	....	....
30	Mount Sanhedrin	90	43	45·79	+0·08	45·87	−0·23	45·64
31	Two Rock	105	10	31·91	+0·01	31·92	−0·75	31·17
32	Paxton	143	35	42·42	−0·06	42·36	−0·27	42·09
33	Cold Spring	174	58	03·10	−0·04	03·06	+0·01	03·07
34	Fisher	180	03	27·40	−0·03	27·37	+1·24	28·61

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) = ± 1″·14.

Paxton, Mendocino County, California. December 7 to December 17, 1878. 30-centimetre theodolite, No. 37. B. A. Colonna, observer.

Number of direction.	Objects observed.	°	′	″	″	″	″	″
	Sanel Mountain	0	00	00·00	....	....	....	....
	Walalla	49	08	41·49	....	....	....	....
40	Cold Spring	77	06	48·60	+0·05	48·65	−0·44	48·21
41	Fisher	93	49	49·39	+0·03	49·42	+1·19	50·61
42	Great Caspar	144	46	24·62	−0·02	24·60	−0·82	23·78
43	Two Rock	177	07	21·08	−0·04	21·04	−0·05	20·99
44	Mount Sanhedrin	225	28	40·16	+0·09	40·25	+0·11	40·36
	Dihel	274	13	09·77	....	....	....	....
	Cole	290	49	23·24	....	....	....	....

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) = ± 1″·18.

(*b*) *Abstract of resulting horizontal directions at each station from local and from figure adjustment*—Completed.

Two Rock, Mendocino County, California. October 17 to November 20, 1879. 45-centimetre theodolite, No. 4. A. F. Rodgers and D. B. Wainwright, observers. July 2 to July 6, 1892. 25-centimetre theodolite, No. 20. E. F. Dickins, observer.

Number of direction.	Objects observed.	Resulting directions from station adjustment.			Reduction to sea level.	Resulting seconds.	Corrections from figure adjustment.	Final seconds in triangulation.
		°	′	″	″	″	″	″
36	Paxton	0	00	00·00	−0·05	59·95	+0·52	00·47
37	Cold Spring	34	41	51·04	+0·02	51·06	+1·08	52·14
38	Fisher	45	06	26·70	+0·03	26·73	−2·73	24·00
39	Great Caspar	109	13	52·68	0·00	52·68	+1·24	53·92
	Cahto	187	03	20·73	....	....	....	....
35	Mount Sanhedrin	264	55	28·59	+0·11	28·70	−0·11	28·59

Probable error of a single observation of a direction (*D.* and *R.*) $= \pm 1''\!\cdot\!31$ in 1879
and (6 *D.* and 6 *R.*) $= \pm 1''\!\cdot\!46$ in 1892.

Fisher, Mendocino County, California. November 22, 1891. 20-centimetre theodolite, No. 95. F. Westdahl, observer. July 8 and 9, 1892. 25-centimetre theodolite, No. 20. F. Westdahl, observer.

Number of direction.	Objects observed.	°	′	″	″	″	″	″
45	Two Rock	0	00	00·00	+0·04	00·04	+1·19	01·23
46	Paxton	51	36	09·53	+0·04	09·57	−0·52	09·05
47	Cold Spring	110	53	44·91	−0·05	44·86	−0·67	44·19
	Clark	185	24	39·25	....	....	....	....
	Dunn	198	51	56·70	....	....	....	....

Probable error of a single observation of a direction (3 *D.* and 3 *R.*) $= \pm 2''\!\cdot\!19$.

(*c*) *Figure adjustment.*

Observation equations.

No.	
1	$0 = -0\cdot749 + (1) - (2) - (10) + (11)$
2	$0 = +1\cdot340 - (1) + (3) - (9) + (10)$
3	$0 = +0\cdot45 - (3) + (6) - (8) + (9) - (12) + (13)$
4	$0 = +1\cdot66 - (7) + (8) - (13) + (15) - (16) + (18)$
5	$0 = +3\cdot43 - (5) + (6) - (12) + (15) - (16) + (17)$
6	$0 = +2\cdot02 - (4) + (6) - (12) + (14) - (28) + (29)$
7	$0 = +1\cdot01 - (14) + (15) - (16) + (20) - (26) + (28)$
8	$0 = -1\cdot52 - (20) + (22) - (24) + (26) - (30) + (33)$
9	$0 = -1\cdot78 - (20) + (21) - (25) + (26) - (35) + (37)$
10	$0 = +1\cdot96 - (21) + (22) - (30) + (31) + (35) - (39)$
11	$0 = -0\cdot55 - (19) + (20) - (26) + (27) - (40) + (44)$
12	$0 = -0\cdot93 - (24) + (27) - (32) + (33) - (40) + (42)$
13	$0 = -1\cdot96 - (31) + (32) - (36) + (39) - (42) + (43)$
14	$0 = +6\cdot49 - (23) + (25) - (37) + (38) - (45) + (47)$
15	$0 = -0\cdot89 - (23) + (27) - (40) + (41) - (46) + (47)$

(*c*) *Figure adjustment*—Continued.

Observation equations—Completed.

No.	
16	$0 = +4{\cdot}7 - 3{\cdot}81(1) + 0{\cdot}81(3) + 0{\cdot}45(9) - 5{\cdot}32(10) + 4{\cdot}87(11)$
17	$0 = +4{\cdot}0 + 0{\cdot}57(3) + 7{\cdot}80(5) - 8{\cdot}37(6) - 6{\cdot}99(7) + 8{\cdot}83(8) - 1{\cdot}84(9) - 1{\cdot}54(16) + 2{\cdot}61(17) - 1{\cdot}07(18)$
18	$0 = +2{\cdot}5 - 1{\cdot}47(4) + 7{\cdot}80(5) - 6{\cdot}33(6) - 2{\cdot}84(16) + 2{\cdot}61(17) + 0{\cdot}23(20) - 4{\cdot}48(26) + 5{\cdot}82(28) - 1{\cdot}34(29)$
19	$0 = +2{\cdot}6 - 4{\cdot}24(20) + 16{\cdot}35(21) - 12{\cdot}11(22) - 2{\cdot}93(24) + 7{\cdot}71(25) - 4{\cdot}78(26) - 8{\cdot}17(30) + 8{\cdot}95(31) - 0{\cdot}78(33)$
20	$0 = +1{\cdot}5 + 2{\cdot}83(19) - 4{\cdot}24(20) + 1{\cdot}41(21) - 2{\cdot}93(24) + 7{\cdot}71(25) - 4{\cdot}78(26) - 1{\cdot}88(31) + 2{\cdot}66(32) - 0{\cdot}78(33) + 3{\cdot}33(42) - 5{\cdot}20(43) + 1{\cdot}87(44)$
21	$0 = -1{\cdot}9 - 9{\cdot}80(19) + 11{\cdot}80(20) - 2{\cdot}00(22) - 0{\cdot}34(24) + 5{\cdot}34(26) - 5{\cdot}00(27) - 1{\cdot}60(30) - 5{\cdot}06(32) - 3{\cdot}46(33)$
22	$0 = +18{\cdot}0 - 5{\cdot}47(23) + 4{\cdot}95(24) + 0{\cdot}52(27) - 2{\cdot}84(32) + 23{\cdot}64(33) - 20{\cdot}80(34) - 7{\cdot}01(40) + 8{\cdot}72(41) - 1{\cdot}71(42)$
23	$0 = -64{\cdot}5 - 1{\cdot}80(23) + 1{\cdot}28(25) + 0{\cdot}52(27) + 0{\cdot}57(31) - 2{\cdot}84(32) + 2{\cdot}27(34) + 11{\cdot}46(37) - 12{\cdot}48(38) + 1{\cdot}02(39) - 7{\cdot}01(40) + 8{\cdot}72(41) - 1{\cdot}71(42)$

Correlate equations.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
(1)	+1	−1													
(2)	−1														
(3)		+1	−1												
(4)						−1									
(5)	....	....	....	....	−1	....	....	....	....	....	....	....	....	....	..
(6)			+1		+1	+1									
(7)				−1											
(8)			−1	+1											
(9)		−1	+1												
(10)	−1	+1	....	....	....	....	....	....	....	....	....	....	....	....	....
(11)	+1														
(12)			−1		−1	−1									
(13)			+1	−1											
(14)						+1	−1								
(15)	....	....	....	+1	+1	....	+1	....	....	....	....	....	....	....	....
(16)				−1	−1		−1								
(17)					+1										
(18)				+1											
(19)											−1				
(20)	....	....	....	....	....	....	+1	−1	−1	....	+1	....	....	....	....
(21)									+1	−1					
(22)								+1		+1					
(23)														−1	−1
(24)												−1			

(*c*) *Figure adjustment*—Continued.

Correlate equations—Continued.

Corrections.	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
(25)	....	....	....	....	....	....	....	....	−1	....	....	....	....	+1	....
(26)							−1	+1	+1		−1				
(27)											+1	+1			+1
(28)						−1	+1								
(29)						+1									
(30)	....	....	....	....	....	....	....	−1	....	−1	....	....	....	....	....
(31)										+1			−1		
(32)												−1	+1		
(33)								+1				+1			
(34)															
(35)	....	....	....	....	....	....	....	....	−1	+1	....	....	....	....	....
(36)													−1		
(37)									+1					−1	
(38)														+1	
(39)										−1			+1		
(40)	....	....	....	....	....	....	....	....	....	....	−1	−1	....	....	−1
(41)															+1
(42)												+1	−1		
(43)													+1		
(44)											+1				
(45)	....	....	....	....	....	....	....	....	....	....	....	....	....	−1	....
(46)															−1
(47)														+1	+1

Correlate equations—Continued.

Corrections.	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}
(1)	−3·81							
(2)								
(3)	+0·81	+0·57						
(4)			−1·47					
(5)	....	+7·80	+7·80	....	....	....	....	....
(6)		−8·37	−6·33					
(7)		−6·99						
(8)		+8·83						
(9)	+0·45	−1·84						
(10)	−5·32	....	....	....	....	....	....	....
(11)	+4·87							
(12)								
(13)								
(14)								

(*c*) *Figure adjustment*—Continued.

Correlate equations—Completed.

Corrections.	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}
(15)	....	....	....	....	....	....	....	....
(16)		−1·54	−2·84					
(17)		+2·61	+2·61					
(18)		−1·07						
(19)					+2·83	− 9·80		
(20)	....	....	+0·23	− 4·24	−4·24	+11·80	....	....
(21)				+16·35	+1·41			
(22)				−12·11		− 2·00		
(23)							− 5·47	− 1·80
(24)				− 2·93	−2·93	− 0·34	+ 4·95	
(25)	....	....	....	+ 7·71	+7·71	....	....	+ 1·28
(26)			−4·48	− 4·78	−4·78	+ 5·34		
(27)						− 5·00	+ 0·52	+ 0·52
(28)			+5·82					
(29)			−1·34					
(30)	....	....	....	8·17	....	− 1·60	....	....
(31)				8·95	− 1·88			+ 0·57
(32)					+2·66	+ 5·06	− 2·84	− 2·84
(33)				− 0·78	−0·78	− 3·46	+23·64	
(34)							−20·80	+ 2·27
(35)	....	....	....	....	....	....	....	....
(36)								
(37)								+11·46
(38)								−12·48
(39)								+ 1·02
(40)	....	....	....	....	....	....	− 7·01	− 7·01
(41)							+ 8·72	+ 8·72
(42)					+3·33		− 1·71	− 1·71
(43)					−5·20			
(44)					+1·87			
(45)	....	....	....	....	....	....	....	....
(46)								
(47)								

(c) *Figure adjustment*—Continued.

Normal equations.

		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
1	0=−0·749	+4	−2	...	...	...	...	...	...	...	...	...	...	...	...	...
2	0=+1·340		+4	−2												
3	0=−0·45			+6	−2	+2	+2									
4	0=+1·66				+6	+2		+2								
5	0=+3·43					+6	+2	+2								
6	0=+2·02	...	...	...	...	...	+6	−2	...	...	...	...	...	...	...	...
7	0=+1·01							+6	−2	−2		+2				
8	0=−1·52								+6	+2	+2	−2	+2			
9	0=−1·78									+6	−2	−2			−2	
10	0=+1·96										+6			−2		
11	0=−0·55	...	...	...	...	...	...	...	...	...	...	+6	+2	...	...	+2
12	0=−0·93												+6	−2		+2
13	0=−1·96													+6		
14	0=+6·49														+6	+2
15	0=−0·89															+6
16	0=+4·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	0=+4·0															
18	0=+2·5															
19	0=+2·6															
20	0=+1·5															
21	0=−1·9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	0=+18·0															
23	0=−64·5															

Normal equations—Continued.

	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}
1	+6·38	......	......	......	......	......	......	......
2	−1·15	+2·41						
3	−0·36	−19·61	−6·33					
4		+16·29	+2·84					
5	......	−12·02	−8·68	......	......	......	......	......
6		−8·37	−12·02					
7		+1·54	+13·37	+0·54	+0·54	+6·46		
8			−4·71	−2·33	+1·61	−9·98	+18·69	
9			−4·71	+8·10	−6·84	−6·46		+10·18
10	......	......	......	−11·34	−3·29	−0·40	......	−0·45
11			+4·71	+0·54	−0·42	+11·26	+7·53	+7·53
12				+2·15	+2·82	−13·18	+27·35	+8·66
13				−8·95	−3·99	+5·06	−1·13	−0·68
14				+7·71	−7·71		+5·47	−20·86

(*c*) *Figure adjustment*—Completed.

Normal equations—Completed.

	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}
15	......	......	......	......	......	− 5·00	+21·72	+18·05
16	+67·39	− 0·37						
17		+271·77	+125·01					
18			+173·74	+ 20·44	+ 20·44	− 21·21		
19				+670·29	+115·69	− 34·57	− 32·94	+ 14·97
20	......	......	......	......	+171·70	− 86·14	− 46·19	− 4·45
21						+333·05	−100·45	− 16·97
22							+1 182·35	+ 99·07
23								+434·92

Resulting values of correlates.

C_1=+0·349 6	C_7=+0·154	C_{13}=−0·522	C_{19}=+0·013 1
C_2=+0·002 9	C_8=+1·813	C_{14}=−1·188	C_{20}=−0·091 2
C_3=+0·367 2	C_9=−1·523	C_{15}=+0·515	C_{21}=−0·037 5
C_4=+0·131	C_{10}=−1·631	C_{16}=−0·100 9	C_{22}=−0·046 1
C_5=−0·811	C_{11}=+0·278	C_{17}=−0·014 1	C_{23}=+0·123 9
C_6=−0·277	C_{12}=−0·901	C_{18}=−0·059 6	

Corrections to angular directions.

"	"	"	"
(1)=+0·731 1	(13)=+0·237	(25)=−0·109	(37)=+1·085
(2)=−0·349 6	(14)=−0·431	(26)=+0·299	(38)=−2·734
(3)=−0·454 4	(15)=−0·526	(27)=+0·120	(39)=+1·235
(4)=+0·365	(16)=+0·717	(28)=+0·084	(40)=−0·437
(5)=+0·236	(17)=−1·003	(29)=−0·197	(41)=+1·193
(6)=−0·225	(18)=+0·146	(30)=−0·229	(42)=−0·816
(7)=−0·032	(19)=−0·169	(31)=−0·750	(43)=−0·048
(8)=−0·361	(20)=+0·017	(32)=−0·274	(44)=+0·109
(9)=+0·345 3	(21)=+0·194	(33)=+0·013	(45)=+1·188
(10)=+0·190 1	(22)=+0·098	(34)=+1·240	(46)=−0·515
(11)=−0·141 8	(23)=+0·702	(35)=−0·108	(47)=−0·673
(12)=+0·720	(24)=−0·899	(36)=+0·522	

(d) Adjusted triangles, California.

No.	Stations.	Observed angles.			Correction.	Spherical angles.	Spherical excess.	Log *s*.	Distances in metres.
		°	′	″	″	″	″		
1	Ross Mountain	56	15	40·806	−0·155	40·651	4·100	5·032 332 5	107 728·96
	Mount Helena	102	52	47·181	−0·454	46·727	4·101	5·101 370 2	126 290·35
	Mount Diablo	20	51	45·654	−0·731	44·923	4·100	4·664 015 9	46 133·45
				13·641			12·301		
2	Ross Mountain	77	51	13·664	−0·487	13·177	3·022	4·918 061 8	82 806·00
	Mount Helena	69	08	49·850	−0·455	49·395	3·021	4·898 471 6	79 153·76
	Mount Tamalpais	33	00	06·142	+0·350	06·492	3·021	4·664 016 0	46 133·46
				9·656			9·064		
3	Ross Mountain	21	35	32·858	−0·332	32·526	3·113	4·779 637 7	60 205·71
	Mount Diablo	28	56	04·448	+0·731	05·179	3·113	4·898 471 8	79 153·80
	Mount Tamalpais	129	28	31·285	+0·350	31·635	3·114	5·101 370 4	126 290·41
				8·591			9·340		
4	Snow Mountain West	25	57	02·45	−0·48	01·97	2·99	4·664 016 0	46 133·46
	Mount Helena	105	16	24·08	+0·23	24·31	2·98	5·007 341 2	101 704·73
	Ross Mountain	48	46	41·98	+0·70	42·68	2·99	4·899 265 7	79 298·64
				8·51			8·96		
5	Mount Sanhedrin	38	55	11·49	−1·72	09·77	1·79	4·899 265 7	79 298·64
	Snow Mountain West	125	58	38·99	−1·25	37·74	1·78	5·009 240 5	102 150·49
	Mount Helena	15	06	18·31	−0·46	17·85	1·79	4·517 094 9	32 892·35
				8·79			5·36		
6	Mount Sanhedrin	63	11	50·07	−0·57	49·50	2·79	5·007 341 2	101 704·73
	Snow Mountain West	100	01	36·54	−0·76	35·78	2·78	5·050 022 3	112 207·60
	Ross Mountain	16	46	43·41	−0·33	43·08	2·79	4·517 094 7	32 892·33
				10·02			8·36		
7	Mount Sanhedrin	24	16	38·58	+1·15	39·73	3·99	4·664 016 0	46 133·46
	Mount Helena	90	10	05·77	+0·69	06·46	3·98	5·050 022 4	112 207·62
	Ross Mountain	65	33	25·39	+0·38	25·77	3·99	5·009 240 5	102 150·49
				9·74			11·96		
8	Cold Spring	25	10	19·43	−0·21	19·22	1·83	4·517 094 8	32 892·34
	Mount Sanhedrin	96	10	53·19	−0·70	52·49	1·82	4·885 837 8	76 884·32
	Snow Mountain West	58	38	53·87	−0·10	53·77	1·83	4·819 819 9	66 041·95
				6·49			5·48		
9	Cold Spring	82	50	21·42	−0·49	20·03	4·80	5·009 240 5	102 150·49
	Mount Sanhedrin	57	15	41·70	+1·02	42·72	4·80	4·937 510 0	86 598·42
	Mount Helena	39	54	10·88	−0·13	10·75	4·80	4·819 820 0	66 041·97
				14·00			14·40		

(*d*) *Adjusted triangles, California*—Continued.

No.	Stations.	Observed angles. °	′	″	Correction. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
10	Cold Spring	57	40	01·99	−0·28	01·71	4·76	4·899 265·7	79 298·64
	Snow Mountain West	67	19	45·12	−1·15	43·97	4·76	4·937 510 0	86 598·42
	Mount Helena	55	00	29·19	−0·59	28·60	4·76	4·885 838 0	76 884·36
				16·30			14·28		
11	Great Caspar	84	14	17·19	+0·24	17·43	1·89	4·819 820 0	66 041·97
	Mount Sanhedrin	36	18	40·21	+0·08	40·29	1·89	4·594 461 5	39 306·25
	Cold Spring	59	27	06·75	+1·20	07·95	1·89	4·757 124·5	57 164·25
				4·15			5·67		
12	Two Rock	129	46	22·36	+1·19	23·55	0·87	4·819 820 0	66 041·97
	Mount Sanhedrin	26	26	59·46	+0·18	59·64	0·86	4·582 889 1	38 272·70
	Cold Spring	23	46	38·99	+0·41	39·40	0·86	4·539 631 0	34 644·24
				0·81			2·59		
13	Two Rock	74	32	01·62	+0·15	01·77	0·75	4·594 461 5	39 306·25
	Cold Spring	35	40	27·76	+0·79	28·55	0·74	4·376 281·7	23 783·83
	Great Caspar	69	47	31·14	+0·77	31·91	0·74	4·582 889·1	38 272·70
				0·52			2·23		
14	Two Rock	155	41	36·02	−1·34	34·68	0·28	4·757 124 5	57 164·25
	Great Caspar	14	26	46·05	−0·52	45·53	0·29	4·539 631 0	34 644·24
	Mount Sanhedrin	9	51	40·75	−0·10	40·65	0·29	4·376 281 5	23 783·81
				2·82			0·86		
15	Paxton	67	39	35·95	−0·38	35·57	0·73	4·594 461 5	39 306·25
	Cold Spring	80	58	04·60	+1·02	05·62	0·72	4·622 928 3	41 968·97
	Great Caspar	31	22	20·70	+0·29	20·99	0·73	4·344 848 3	22 123·22
				1·25			2·18		
16	Paxton	100	00	32·39	+0·39	32·78	0·51	4·582 889 1	38 272·70
	Cold Spring	45	17	36·84	+0·23	37·07	0·51	4·441 247 8	27 621·54
	Two Rock	34	41	51·11	+0·57	51·68	0·51	4·344 848 4	22 123·22
				0·34			1·53		
17	Paxton	148	21	51·60	+0·54	52·14	0·46	4·819 820 0	66 041·97
	Cold Spring	21	30	57·85	−0·18	57·67	0·45	4·664 442 7	46 178·81
	Mount Sanhedrin	10	07	11·36	+0·19	11·55	0·45	4·344 848 3	22 123·22
				0·81			1·36		
18	Paxton	32	20	56·44	+0·77	57·21	0·52	4·376 281 6	23 783·82
	Great Caspar	38	25	10·44	+0·48	10·92	0·52	4·441 247 8	27 621·54
	Two Rock	109	13	52·73	+0·71	53·44	0·53	4·622 928·1	41 968·95
				59·61			1·57		

(*d*) *Adjusted triangles, California*—Completed.

No.	Stations.	Observed angles. °	′	″	Correction. ″	Spherical angles. ″	Spherical excess. ″	Log *s*.	Distances in metres.
19	Paxton	80	42	15·65	+0·92	16·57	1·62	4·757 124 5	57 164·25
	Great Caspar	52	51	56·49	−0·04	56·45	1·62	4·664 442 6	46 178·80
	Mount Sanhedrin	46	25	51·57	+0·27	51·84	1·62	4·622 928 2	41 968·96
				3·71			4·86		
20	Paxton	48	21	19·21	+0·15	19·36	0·81	4·539 631 0	34 644·24
	Two Rock	95	04	31·25	+0·63	31·88	0·80	4·664 442 5	46 178·79
	Mount Sanhedrin	36	34	10·82	+0·36	11·18	0·81	4·441 247 7	27 621·53
				1·28			2·42		
21	Fisher	40	59	....	....	34·54	0·63	4·376 281 6	23 783·82
	Great Caspar	74	52	55·45	+1·99	57·44	0·64	4·544 106 0	35 003·06
	Two Rock	64	07	25·95	+3·97	29·92	0·63	4·513 522 2	32 622·87
							1·90		
22	Fisher	92	35	....	....	42·38	0·69	4·622 928 2	41 968·96
	Great Caspar	36	27	45·01	+1·51	46·52	0·69	4·397 379 4	24 967·75
	Paxton	50	56	35·18	−2·01	33·17	0·69	4·513 522 2	32 622·87
							2·07		
23	Fisher	151	53	....	....	17·50	0·09	4·594 461 5	39 306·25
	Great Caspar	5	05	24·31	+1·23	25·54	0·10	3·869 319 5	7 401·50
	Cold Spring	23	01	18·85	−1·60	17·25	0·10	4·513 522 2	32 622·87
							0·29		
24	Fisher	51	36	09·53	−1·70	07·83	0·58	4·441 247 8	27 621·54
	Two Rock	45	06	26·78	−3·25	23·53	0·58	4·397 379 3	24 967·74
	Paxton	83	17	31·62	−1·24	30·38	0·58	4·544 106 0	35 003·06
				7·93			1·74		
25	Fisher	110	53	44·82	−1·86	42·96	0·21	4·582 889 1	38 272·70
	Two Rock	10	24	35·67	−3·82	31·85	0·20	3·869 319 5	7 401·50
	Cold Spring	58	41	46·61	−0·81	45·80	0·20	4·544 106 0	35 003·06
				7·10			0·61		
26	Fisher	59	17	35·29	−0·16	35·13	0·13	4·344 848 3	22 123·22
	Paxton	16	43	00·77	+1·63	02·40	0·13	3·869 319 6	7 401·50
	Cold Spring	103	59	23·45	−0·58	22·87	0·14	4·397 379 4	24 967·75
				59·51			0·40		

(*e*) *Precision of the Western or Coast Range series of triangles.*

For a fair estimate of the precision of the adjusted triangulation, we have in the first place the mean error of an observed angle as derived from 75 corrections to directions determined from the 23 normal equations—

$$m = \sqrt{\frac{2[vv]}{c}} = \sqrt{\frac{2 \times 22{\cdot}58}{23}} = \pm 1''{\cdot}40$$

To find the probable error of the length of the side Great Caspar to Fisher, which can be reached from the side Mount Helena-Mount Diablo by six triangles, we make use of the usual expressions—

$$u_{a_n} = \frac{2}{3}(\delta_{a_n})^{-2} \sum_{a_1}^{a_n} [\delta_A^2 + \delta_A \delta_B + \delta_B^2] \quad \text{and} \quad e_{a_n} = 0{\cdot}6745 m \sqrt{u_{a_n}}$$

In this case—

$$\delta_{a_n} = 13{\cdot}3, \quad \sum [\delta_A^2 + \delta_A \delta_B + \delta_B^2] = 83{\cdot}8, \quad u_{a_n} = 0{\cdot}316 \text{ and } e_{a_n} = \pm 0{\cdot}531 m.$$

To this probable error, due to angular measures, must be added the part arising from the uncertainty of the starting side. The probable error of the side Mount Helena-Mount Diablo was found to be $\pm 0{\cdot}295$ metre or $\frac{1}{366000}$ part of its length. The corresponding probable error for Great Caspar-Fisher is $\pm 0{\cdot}089$ metre, and the total probable error is $\sqrt{(0{\cdot}531)^2 + (0{\cdot}089)^2} = \pm 0{\cdot}538$ metre, which is $\frac{1}{60600}$ part of the length.

The distance between the middle points of the lines Mount Helena-Mount Diablo and Great Caspar-Fisher projected on the thirty-ninth parallel is about 120 kilometres (74 statute miles). The average probable error of the triangulation may be taken as $\frac{1}{2}\left(\frac{1}{366000} + \frac{1}{60600}\right) = \frac{1}{104000}$ part of the length. The uncertainty in length of the triangulation between the Yolo Base Net and the Pacific is therefore 1·15 metres.

G. SOME STATISTICS OF THE TRANSCONTINENTAL TRIANGULATION.

In judging of the extent and value of this work, it will be convenient to have for comparison a collection of some leading statistical numbers bearing upon the arrangement and results of the preceding computations.

The following table exhibits the approximate distances between the adjacent base nets as measured from the middle of a junction line through the axis of the intervening triangulation to the middle of the opposite junction line. There is also given the number of trigonometric stations in the chain of triangles and the number of conditional equations involved and satisfied for each connecting link.

Designation of triangulation.	Starting and junction lines.	Distances between sides of base nets.	Number of intermediate triangulation stations.	Number of conditional equations involved.
		km.		
1 The Eastern Shore series	Cape May Light to Cape Henlopen Light Finlay to Linstid	140	14	18+15
2 The Allegheny series	Webb to Marriott Summersville to Ivy	445	20	22+33
3 The Ohio series	Piney to Pigeon Reizin to Culbertson	280	23	50
4 The Indiana series	Green to Stout Hunt City to Claremont	216	15	34
5 The Illinois series	Hunt to Newton Clark Mound to Dreyer	171	12	33
6 The Missouri series	Insane Asylum to Kleinschmidt Christian to Belche	192	22	65
7 The Missouri and Kansas series	Hubbard to Hughes Vine Creek to Iron Mound	402	36	77
8 The Kansas and Colorado series	Thompson to Heath Holcomb Hill to Big Springs	560	42	99
9 The Rocky Mountains series	Divide to Big Springs Mount Nebo to Ibepah	780	12	28
10 The Nevada and California series	Mount Nebo to Ibepah Mount Helena to Mount Diablo	850	16	40
11 The Western or Coast Range series	Mount Helena to Mount Diablo Fisher to Cold Spring	160	8	23

The total number of principal triangulation stations, not counting those of the base nets, is 220. Adding to these the latter, or 88, we have for the total number of principal stations 308. To these must be added about 240 subordinate stations—i. e., those which connect the geodetic and astronomic positions.

The total number of conditions in the above series is 537. Adding to these the 206 conditions in the base nets, the grand total of conditions subsisting and satisfied is 743.

The following tables contain statistics relating to the angular measures, the closure of triangles, and the degree of accord between any two adjacent base lines when connected by a series of triangles.

With respect to the closure of the triangles (π plus spherical excess minus the sum of the angles), we find the number of cases in excess to those in defect in the ratio 36 to 34, nearly. If $\varDelta$ equal the closing error, and n the number of triangles, the column headed "Mean error of an angle" gives the quantity $a = \sqrt{\frac{[\varDelta^2]}{3n}}$ with an average value of $\pm 0''.77$. The column headed "Probable error of an adjusted direction" is given by $d = 0.675 \sqrt{\frac{[vv]}{c}}$ where $c =$ number of conditions.

The average value is $\pm 0''.44$

H. SUMMARY OF RESULTS RELATING TO ANGULAR MEASURES.

Designation of locality.	Triangle closing errors. Number of +	Number of −	Sum of +	Sum of −	Number of triangles.	Mean error of an angle.	Probable error of a resulting direction.
			"	"		"	"
Eastern Shore series	14	14	26.55	22.62	28	±1.22	±0.72
Kent Island Base Net	6	6	8.42	7.54	12	0.96	0.41
Allegheny series	33	* 18	46.79	24.20	52	0.98	0.45
St. Albans Base Net	11	14	11.35	23.15	25	1.04	0.47
Ohio series	20	24	24.53	25.77	44	0.85	0.45
Holton Base Net	4	11	4.40	7.47	15	0.58	0.34
Indiana series	15	12	13.60	8.11	27	0.60	0.34
Olney Base Net	13	22	11.01	16.18	35	0.54	0.29
Illinois series	10	18	6.85	15.37	28	0.57	0.34
American Bottom Base Net	7	9	11.31	24.17	16	1.59	0.82
Missouri series	36	28	49.72	19.95	64	0.81	0.66
Versailles Base Net	17	14	16.00	11.83	31	0.64	0.40
Missouri-Kansas series	41	29	36.40	24.90	70	0.60	0.35
Salina Base Net	8	6	8.73	7.10	14	0.75	0.44
Kansas-Colorado series	48	48	50.24	46.05	96	0.75	0.50
El Paso Base Net	7	9	4.94	10.11	16	0.68	0.40
Rocky Mountain series	13	10	11.29	7.93	23	0.57	0.32
Salt Lake Base Net	18	15	14.43	12.28	33	0.66	0.32
Nevada-California series	15	15	8.00	9.17	30	0.42	0.23
Yolo Base Net	7	12	2.09	10.79	19	0.51	0.24
Western or Coast Range series	14	9	16.56	24.91	23	±1.37	±0.67
Sums	357	343	383.21	359.60	701		
Average value from 701 triangles						±0.77	
Average value from 1 660 directions							±0.44

* One triangle closes exactly.

I. ACCORD OF THE BASE LINES.

In the adjustment of the triangulation between two adjacent base nets the length equation has been derived from the angles as given by the station adjustments previous to any further adjustment, the triangles not even having been closed. Any route might have been selected, but such angles as differ least from 90° have been chosen. Spherical angles have been used, the logarithms of the terminal lines having been corrected for difference in arc and sine. In the solution of the normal equations the length equation was assigned the last place in order, so that the discrepancy was corrected for the adjustment of all the other equations, thus showing the final discrepancy which was distributed over the figure, and which was the same that would have been obtained if the length equation had not been formed until all the other equations had been adjusted.

The following table shows the discord in length between adjacent base lines as computed through the intervening triangulation, derived in the manner explained above. A plus sign indicates that the base to the east gives the greater length. The discrepancy is given in units of the seventh decimal place of logarithms and also in parts of the length.

Base lines.	Discrepancy.	
	In logarithm.	One part in—
Kent Island and St. Albans	+ 11	395 000
St. Albans and Holton	− 24	181 000
Holton and Olney	− 71	61 200
Olney and American Bottom	− 6	724 000
American Bottom and Versailles	+ 86	50 500
Versailles and Salina	+169	25 700
Salina and El Paso	− 92·3	47 000
El Paso and Salt Lake	+ 85·4	50 840
Salt Lake and Yolo	+ 82·6	52 600

PART IV.

THE RESULTS OF THE ASTRONOMIC DETERMINATIONS OF LATITUDE.

CONTENTS OF PART IV.

IV. THE RESULTS OF THE ASTRONOMIC DETERMINATIONS OF LATITUDE

CONNECTED WITH THE TRANSCONTINENTAL TRIANGULATION.

A. GENERAL REMARKS.

There are more than 100 stations at which the latitudes were determined astronomically and almost exclusively by Talcott's method. Many of these determinations had been made for purposes other than those for which they are now utilized. They date back to the year 1846, a time when the great practical value of the micrometric or Horrebow-Talcott method* had been fairly recognized, only to be further confirmed when a greater choice of stars with superior catalogue places became available. The latest date when Airy's zenith sector was employed on the Survey for latitude work was in 1850 and 1851. There are also a few stations of a permanent character where the ordinary observatory instruments were used. Altogether there are some 19 000 individual observations for latitude collected and utilized in connection with this part of the geodetic work.

B. INSTRUMENTS.

A zenith sector made by Troughton & Simms of London according to Airy's design was used at four stations: Webb, Hill and Soper, in Maryland, and Causten, District of Columbia, in 1850–51. This instrument is described in detail in Clarke's Geodesy,† pp. 182–185. It was an instrument for making absolute measures of comparatively small zenith distances (not exceeding 15°). The inclination of the telescope was determined by four microscopes reading against two arcs, one near the object glass and the other near the eyepiece, graduated to 5′ spaces and having a radius of 20·5 inches. These graduated arcs, three levels and the telescope axis, were carried by a revolving frame, which was placed in the plane of the meridian and could be reversed quickly about its vertical axis. This vertical axis was not continuous, but consisted

* For a short historical notice of the Talcott method, a description of instrument, statement of formulæ, and method of reduction, the reader may consult Appendix No. 14, Coast and Geodetic Survey Report for 1880, pp. 245–259; further information will be found in Chauvenet's Manual of Spherical and Practical Astronomy, 1863, and in other treatises and publications, e. g., C. L. Doolittle's Treatise on Practical Astronomy (4th edition of 1893) and Dr. T. Albrecht's "Formeln und Hülfstafeln für geographische Ortsbestimmungen," Leipzig, 1894 (3d edition), pp. 75 to 84. A revised edition of Appendix No. 14 has since been published in the Superintendent's annual report for the fiscal year 1897–98. Appendix No. 7, by J. F. Hayford, assistant.

† Geodesy by Col. A. R. Clarke, Oxford, Clarendon Press, 1880. The instrument is figured on p. 183. See also "Ordnance Survey; Astronomical Observations, etc.," 1842 to 1850. London, 1852.

merely of a lower cone carrying the whole weight of the frame and an upper adjustable cone with its vertex downward, which was supposed to furnish just enough pressure to make the axis of revolution stable.

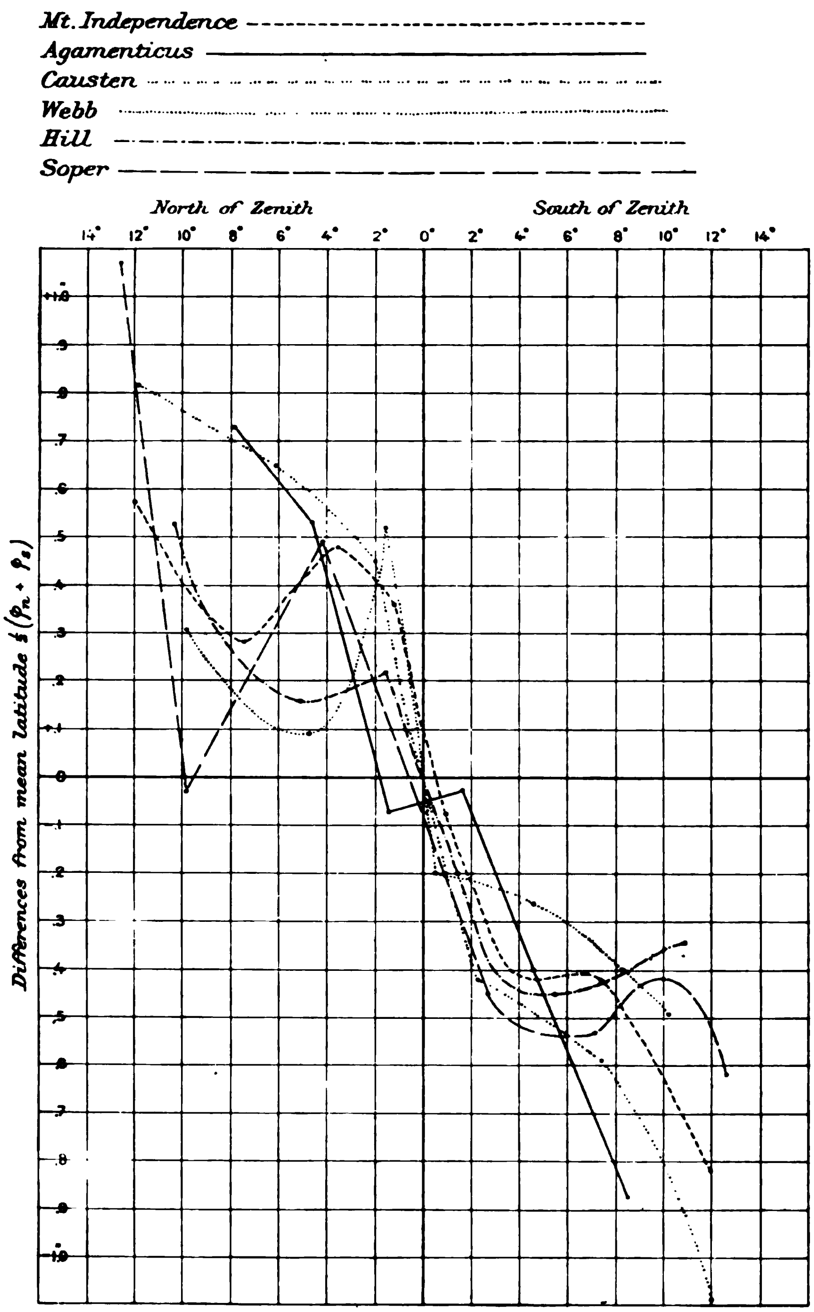
All observations were made with the telescope in the meridian, and with the star near the middle of the field of the telescope. Two pointings, with the corresponding arc and level readings, were made upon each star, with a reversal of the revolving frame 180° in azimuth between them.

The probable error of a single observation was but little greater than with the zenith telescope, which was used later. But it was found that in all the observations made with the zenith sector at the four stations named above and at Mount Independence and Agamenticus, Maine, the latitude derived from observations upon stars north of the zenith were systematically greater (by 0″.8 on an average) than those derived from southern stars. These systematic errors are indicated graphically in the accompanying diagram, reproduced from astronomic report December 9, 1869, plotted from the actual observations at these six stations. It will be noticed that the error is apparently proportional, on an average, to the zenith distance of the star. Various attempts have been made to account for these systematic errors by ascribing them to imperfect graduation, to a yielding of the cones forming the vertical axis, to a distortion of the graduated arcs as the revolving frame yielded under its own weight, to defects in the assigned star places, to deviation of the telescope from the meridian, and to other causes. Because of these unexplained systematic errors and because of the unwieldiness of the instrument in transportation the zenith sector was superseded on the Coast Survey by the zenith telescope after the sector had been used at six stations only.

In computing the latitude from observations with the zenith sector the latitudes were first separated into two groups, one from stars north of the zenith and the other from southern stars; the indiscriminate mean of the results in each group was taken, and the adopted latitude is the simple mean of the two group means. This method of reduction eliminates the systematic errors, provided said errors are proportional to the zenith distance of the star observed, and provided the mean zenith distance of the northern group is equal to the mean zenith distance of the southern group. The stars were purposely selected in such a way as to nearly fulfill this last condition. It was not considered advisable to assign different relative weights, depending upon the number of observations to the various stars, since it was evident that the systematic errors were much larger than the outstanding accidental errors of observation. The probable error assigned to the adopted latitude was computed by the formula $\sqrt{\frac{0.455\ \Sigma v^2}{n\ (n-1)}}$, in which n is the number of stars observed at the station, and the v's are the residuals obtained by subtracting the mean result from each star from the *adopted latitude*. It is believed that the probable error as thus computed is sufficiently large to include the uncertainty arising from the obscurity connected with any systematic errors.

The observations by the Horrebow-Talcott method were made with instruments of three types, commonly called in the Coast and Geodetic Survey zenith telescopes, transit and meridian telescopes, respectively. These instruments are illustrated in Appendix No. 7 of the Coast and Geodetic Survey Report for 1898, zenith telescope Nos. 1 to 4 in figure 6, and the meridian telescopes in figure 2; and in Appendix No. 14 of the

SYSTEMATIC ERRORS IN LATITUDE



Report for 1880 the transit is shown in illustration No. 62 and the older form of zenith telescope in illustration No. 68.

Particulars of these three instruments are contained in the tabular form below:

Instrument.	Made by—	When made.	Focal length.	Clear aperture.	Magnifying power.	One division of level.	One turn of micrometer.	Remarks.
			cm.	*mm.*		″	″	
Zen. Tel. M. A.	....	....	....	....	....	1·3	45	Property of United States Military Academy at West Point.
Zen. Tel. No. 1	T & S.*	1847	117	82	{53, 80}	0·9 to 1·5	46 and 47	New micrometer in 1879.
Zen. Tel. No. 2	T. & S.	....	116	76	61	0·9 to 1·2	45	Remodeled 1891 for international latitude observations at Honolulu.
Zen. Tel. No. 3	T. & S.	1848	117	76	61	1·0 to 2·6	46·6	
						u 0·81†		
					100	*l* 0·85	47·6	After reconstruction at Coast and Geodetic Survey Office in 1891.
Zen. Tel. No. 4	T. & S.	1849	117	76	100	0·9 to 2·2	43·7 and 44·7	New micrometer in 1878.
						u 1·6†		
						l 1·4	44·6	After reconstruction at Coast and Geodetic Survey Office in 1891.
Zen. Tel. No. 5	W.*	1850	118	95	....	0.7 to 2·2	41·4	
Zen. Tel. No. 6	W.	1854	66	50	66	0·8 to 2·2	76·2	
Transit No. 4	T. & S.	1848	119	70	90	2·1	41·4	Fitted for latitude observations in 1881; modified at Coast and Geodetic Survey Office in 1890.
Transit No. 6	T. & S.	1849	117	70	105	1·6 to 2·4	44·2	Fitted for latitude observations in 1881.
Mer. Tel. No. 1	W.	1868	78	70	60	0·9 to 1·9	65·4	
							64·4	Furnished with new objective in 1872.
							66·0	Remodeled at Coast and Geodetic Survey Office in 1893.
Mer. Tel. No. 2	W.	1874	79	72	77	0·7 to 1·7	64·0 to 65·9	
							65·6	New micrometer in 1894.
Mer. Tel. No. 3	K.*	1876	80	70	70	0·9 to 3·6	63·8	
							65·1	New micrometer in 1894.
Mer. Tel. No. 7	W.	1870	66	54	70	1·0 to 2·3	77·1	Three different objectives.
							79·1	
							78·3	
Mer. Tel. No. 9	....	....	65	52	43	1·0 to 2·1	100·7	
							80·7	New micrometer in 1893.
Mer. Tel. No. 13	W.	Before 1871	66	50	72	2·5 to 2·7	77·8	
Mer. Tel. No. 16	F. & Co.*	....	78	66	....	1·9 to 2·6	67·3	

* T. & S. = Troughton & Simms. W. = Würdemann. F. & Co. = Fauth & Company. K. = E. Kübel.

† These remodeled carry *two* latitude levels—an upper and a lower.

C. DETERMINATION OF THE MEAN PLACES OF STARS.

The star catalogues upon which the computations made during the past year (1898) of the north polar distance of latitude stars have been based are as follows (the date being that to which observations given in the catalogue are reduced):

1755. Auwers' Bradley
1790. Fedorenko
1800. D'Agelet (Gould)
1800. Bailey's Lalande
1800. Piazzi
1810. Groombridge
1825. Weisse's Bessel
1830. Cambridge
1830. Pond
1830. Struve
1830. Argelander, Abo
1836., 1850. Rümker
1840. Armagh
1840. Cape
1840., 1845. Greenwich, 12-year
1845. Pulkowa
1845. Radcliffe
1845., 1860., 1875. Paris
1850. Greenwich, 6-year
1850. Cape
1855. Bonn
1855. Pulkowa
1860. Cape
1860. Greenwich, 7-year
1860. Radcliffe
1860. Washington, Frisby's Yarnall
1862., 1863., 1864. Radcliffe
1864. Greenwich, 7-year
1865. Brussels
1865. Pulkowa
1870. Glasgow
1870. Melbourne
1870. Leiden
1872. Greenwich, 9-year
1875. Auwers' Fundamental
1875. Armagh
1875. Cordoba
1875. Rome
1875. Romberg
1875. Harvard
1880. Cape
1880. Greenwich, 10-year
1880. Ann Arbor (M. S.)
1885. Pulkowa
1890. Greenwich, 5-year
1890. Radcliffe
1890. Glasgow
1890. Cincinnati

Greenwich annual volumes 1887 to 1895, inclusive, and Edinburgh observations by Henderson and Smyth of various epochs.

The present practice in computing mean places is as follows: The north polar distance and related quantities are abstracted for a given star from each of the above catalogues in which that star occurs. To the north polar distance from each catalogue is applied a systematic correction for the known systematic errors of that catalogue as developed by the researches of Prof. Lewis Boss,* supplemented for catalogues not treated by him by corrections from similar researches by other authorities. The resulting north polar distances are reduced to a common epoch (1890) by using the first two terms of the precession and an assumed approximate value of the proper motion. To these reduced north polar distances are assigned relative weights derived from the researches of Professor Boss and other authorities referred to above. By a rigid least square reduction the most probable correction to the assumed proper motion and the most probable value of the north polar distance at the epoch 1890, together with the probable errors of those quantities, are then derived, whence the declination and its probable error at any epoch becomes known.

This, the present method of computing mean places, has been developed and put into use gradually. In connection with the latitude observations along the thirty-ninth parallel, extending over a period of half a century, many of the mean places were computed by methods which at the time were satisfactory for the purpose, yet crude as compared with the present means. To recompute all such mean places would not be justified by the small improvement in accuracy to be expected; it did seem desirable,

*See report on the "Survey of the Northern Boundary from the Lake of the Woods to the Rocky Mountains;" Washington, 1878. (Pp. 409–619.)

however, to reexamine and eliminate the larger discrepancies arising from such mean place computations.

Thus, wherever it was found that $\triangle\varphi$, the residual for any pair from the indiscriminate mean was greater than 3½ times the probable error of the mean for *that pair*, as given by the formula $\dfrac{e^2_{xx} + e^2_{n_1}}{2}$, in which the larger of the two values for $e_{\frac{xx}{2}}$ was used as in computing the weight (see pages 624–625), the mean place computation for that pair was carefully revised by present methods, to determine, if possible, whether the large residual was due to defects in the assigned mean places or to other causes. The mean places of 106 stars were thus revised. In 56 cases the required correction to the north polar distance was found to be positive and in 50 cases negative; the largest plus correction was 7″·7 and the largest minus correction 5″·9; the mean of all the corrections without regard to sign was 1″·01 and the mean of all with regard to sign + 0″·18. The above facts indicate that the defects in the old north polar distances are in the main accidental. Although the number of star catalogues has greatly multiplied since the observations and computations for latitude were made, it may be said that if all the mean places were reduced to a modern basis the value assigned to the mean latitude of the thirty-ninth parallel triangulation would not be thereby changed from its present value more than 0″·05 at most, and that it is improbable that it would be changed more than 0″·02.

D. WEIGHTS AND PROBABLE ERRORS.

The probable errors and relative weights assigned to the separate pairs were computed as indicated below:

Let n = the total number of observations and n' the number upon any pair, p = the number of pairs, $\triangle$ = the difference between each individual result and the mean result deduced from that pair, $\Sigma\triangle^2$ = the sum of all the $\triangle^2$'s, and e = the probable error of a single observation for latitude, then

$$e^2 = 0{\cdot}455\frac{\Sigma\triangle^2}{n-p} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Let $e_{\frac{**}{2}}$ be the probable error of the mean of two declinations. A value for $e_{\frac{**}{2}}$ for the stars observed at a station may be obtained in two ways—namely, from the computation of the mean places of the stars and from the latitude computation itself.

The computation of the mean places furnishes, for each star, the value of e_{*_1} the probable error of declination of that star. If the probable errors of the declinations of the stars of a pair are e_{*_1} and e_{*_2}, the probable error of the mean of the two declinations is—

$$e_{\frac{**}{2}} = \sqrt{\frac{e^2_{*1} + e^2_{*2}}{4}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and neglecting the difference between e_{*_1} and e_{*_2} we may write $e^2_{\frac{**}{2}} = \frac{e^2_*}{2}$ and a mean

value of e^2_{**} for the station is—

$$e^2_{\frac{**}{2}} = \frac{\Sigma e^2_*}{2N} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

in which N is the total number of stars observed at the station and Σe^2_* is the sum of all the e^2_*'s given by the mean place computations of those stars.

To deduce a mean value for e_{**} for the station from the latitude observations, without reference to the probable errors of declinations furnished by the preceding mean place computation the following process suffices. From the ordinary law of combination of errors—

$$e^2_{\frac{**}{2}} = e^2_p - \varepsilon^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

in which e_p is the probable error of the mean result from a pair, and ε is the probable error in that mean result arising from observation only and therefore exclusive of errors of declination.

A mean value of e^2_p for the station is obtained from the differences $\triangle\varphi$ between the mean results from the separate pairs and the indiscriminate mean of all the pairs. Thus—

$$e^2_p = \frac{0{\cdot}455 \; \Sigma\triangle\varphi^2}{p - 1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Each pair furnishes a value for ε^2 of the following form—

$$\varepsilon^2 = \frac{e^2}{n^1}$$

in which n^1 is the number of observations upon that pair. Giving the various values of ε^2 equal weight, their mean is—

$$\varepsilon^2 = \frac{e^2}{p} \Sigma \frac{1}{n^1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The mean values of e^2_p and ε^2 for the station, from (5) and (6) being substituted in (4), there is obtained a mean value of $e^2_{\frac{**}{2}}$ for the station.

In combining the mean results from the separate pairs, it is desirable to give them relative weights which are inversely proportional to the squares of their probable errors. Accordingly, the weight assigned to each pair is—

$$w = \left(e^2_{\frac{**}{2}} + \frac{e^2}{n^1} \right)^{-1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

in which the value used for $e^2_{\frac{**}{2}}$ for each pair is always the *larger of the two values*

given for that pair by (4) and (2). This treatment is based upon the supposition that if (4) gives a greater value for $e^2_{\frac{**}{2}}$ than (2), there are other sensible errors *peculiar to the pair* in addition to the assigned declination errors.

The only cases in which exceptions have been made to the weights stated in (7) are those in which one star is treated in connection with two or more others to form two or more pairs, which are not, therefore, independent pairs. If one star is combined with each of two others to form two pairs, each of these pairs was given a weight two-thirds as large as indicated by (7). If one star is combined with each of three others to form three partially dependent pairs, each of these pairs was given a weight one-half as large as that indicated by (7). A single star, nearly in the zenith, and observed in both positions of the instrument, was given the weight—

$$w = \left(2e^2_{\frac{**}{2}} + \frac{e^2}{n'} \right)^{-1}$$

The probable error of the weighted mean of resulting latitude is—

$$e_\varphi = \sqrt{\frac{0{\cdot}455 \ \Sigma wv^2}{(p-1) \ \Sigma w}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (8)$$

in which the residuals, v, are the differences between the mean results from the separate pairs and the weighted mean of all.

In the following tabular statements of results the values given in the column headed "Adopted seconds of mean N. P. D." are the mean north polar distances at the beginning of the year of observation, which were adopted and used in the computation. When the same star appears in the tabulations for different stations, the various values for its north polar distance do not necessarily depend upon the same data. It frequently happens that the place given for a star at late date depends in part upon data which were not available when the computation for an earlier date was made.

Star numbers given without any modification refer to the British Association Catalogue; numbers inclosed in a parenthesis, thus ( ), refer to the Greenwich Ten Year Catalogue for the epoch 1880; and numbers in a square bracket, thus [ ], refer to the Coast Survey Catalogue given in Appendix No. 7 of the 1876 report. An asterisk placed upon a star number serves to call attention to the fact that the star is also used in another pair or pairs at that station. The subscripts P, F, M, indicate the preceding, following, and mean of two close stars, respectively.

The revisions of mean places of stars and of the latitude results here given, in general, were placed in charge of Mr. J. F. Hayford.

E. ABSTRACTS OF RESULTING LATITUDES AS OBSERVED AT THE ASTRONOMIC STATIONS OF THE TRANSCONTINENTAL TRIANGULATION.

I. EASTERN SHORE SERIES.

(1) *Latitude at Cape May, New Jersey.* E. Smith and F. H. Parsons. T. and S. Transit No. 6. May 13–27, 1881. One division of level $= 2''\cdot455$, observed at the office in April, 1881. One turn of micrometer $= 44''\cdot198$, derived from observations upon Polaris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
4 607	4 656	32·85	26·08	5	5	38 55 44·73	−0·07
4 706	4 742	38·50	00·58	4	5	45·12	−0·46
4 758	4 812	30·38	14·44	3	4	44·12	+0·54
4 876	4 937	24·47	04·25	4	5	44·72	−0·06
4 974	5 031	54·52	36·01	5	5	44·80	−0·14
5 076	5 084	35·14	17·12	5	5	45·12	−0·46
(2 386)	(2 421)	00·27	22·66	5	5	45·37	−0·71
5 168	5 178	30·59	37·67	4	5	46·05	−1·39
5 249	5 293	56·36	37·51	4	5	44·26	+0·40
5 313	5 322	48·99	51·19	3	4	44·35	+0·31
5 348	5 426	59·70	26·28	4	5	43·72	−0·94
5 460	5 496	22·08	03·25	5	5	45·07	−0·41
5 525	5 599	59·98	04·52	5	5	44·11	+0·55
5 619	(2 617)	27·94	50·32	4	5	43·58	+1·08

Indiscriminate mean $= 38^\circ\ 55'\ 44''\cdot65$.
Weighted mean $= 38\ \ 55\ \ 44\ \ \cdot66 \pm 0''\cdot12$.
$e = \pm 0''\cdot52$.

60 observations, 14 pairs. Twelve observations were rejected at this station; the level was considered to be defective.

[Reduction to pole or station mark $+ 1''\cdot28$.]

I. EASTERN SHORE SERIES—continued.

Latitude at Cape May, New Jersey. C. H. Sinclair. Zenith telescope No. 6. May 5-9, 1891. One division of level = 0''·96. One turn of micrometer = 76''·094, derived from latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		"	"			° ′ "	"
4 384	4 438	04 ·44	09 ·08	4	8	38 55 44 ·19	+0 ·58
(1 130)	4 564	38 ·62	39 ·40	4	8	44 ·62	+0 ·15
4 607	*4 656	33 ·33	23 ·87	4	5	44 ·48	+0 ·29
*4 656	*4 701	23 ·87	36 ·55	4	5	44 ·06	+0 ·71
4 675	*4 701	12 ·49	36 ·55	2	5	44 ·09	+0 ·68
4 706	4 742	30 ·66	47 ·75	4	8	44 ·84	−0 ·07
4 758	4 812	18 ·25	53 ·17	4	8	44 ·43	+0 ·34
4 876$_F$	4 937	57 ·78	32 ·15	4	8	44 ·80	−0 ·03
4 974$_F$	5 031	15 ·73	51 ·43	3	8	44 ·86	−0 ·09
(1 261)	5 071	53 ·85	55 ·92	3	8	45 ·33	−0 ·56
5 076	5 084	45 ·62	25 ·62	3	8	45 ·10	−0 ·33
(1 275)	(1 289)	07 ·10	22 ·67	4	8	44 ·41	+0 ·36
5 168	5 178$_M$	29 ·70	35 ·14	3	8	45 ·72	−0 ·95
5 249	5 293	48 ·70	23 ·09	4	8	44 ·10	+0 ·67
5 313	5 322	31 ·47	33 ·64	4	8	44 ·97	−0 ·20
5 348	5 426	36 ·71	59 ·50	3	8	44 ·61	+0 ·16
5 463	5 473	36 ·87	17 ·61	4	8	44 ·18	+0 ·59
5 525	5 599	21 ·44	16 ·38	3	8	45 ·32	−0 ·55
5 619	(1 393)	36 ·12	56 ·97	3	8	45 ·06	−0 ·29
5 643	*(1 404)	23 ·64	56 ·24	3	5	45 ·88	−1 ·11
*(1 404)	5 752	56 ·24	04 ·77	3	5	44 ·95	−0 ·18

Indiscriminate mean = 38° 55′ 44''·76.
Weighted mean = 38 55 44 ·77 ± 0''·07.
$e = \pm 0''·28$.

73 observations, 21 pairs.

[Reduction to pole or station mark + 1''·28.]

I. EASTERN SHORE SERIES—continued.

(2) *Latitude at Cape Henlopen, Delaware.* O. B. French. Meridian telescope No. 9. September 6–10, 1897. One division of level = 1''·81, observed at the office in March, 1893. One turn of micrometer = 80''·672, derived from observations upon two circumpolars at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		''	''			° ' ''	''
6 585	6 650	47·97	08·62	3	7	38 46 40·18	−0·18
6 690	(3 190)	24·29	51·30	3	7	39·99	+0·01
(3 232)	6 771	23·12	40·01	4	10	40·10	−0·10
6 808	6 802	53·04	13·55	2	5	40·98	−0·98
6 834	6 839	22·24	16·31	4	9	39·80	+0·20
6 862	6 868	30·78	54·47	3	6	40·16	−0·16
(3 315)	(3 324)	41·15	49·55	4	8	39·96	+0·04
6 926	(3 331)	12·98	28·07	4	9	39·64	+0·36
(3 338)	6 976	52·63	50·99	4	8	39·94	+0·06
7 017	7 088	39·02	48·81	3	7	39·96	+0·04
(3 445)	(3 465)	45·20	09·33	3	4	40·41	−0·41
(3 486)	*7 294	09·11	17·83	3	5	39·84	+0·16
7 256	*7 294	03·19	17·83	3	5	40·00	0·00
7 313	*7 336	49·84	26·14	3	5	40·23	−0·23
*7 336	7 398	26·14	14·10	3	5	39·49	+0·51
7 465	7 480	33·71	49·65	3	7	39·52	+0·48
7 520	7 582	41·41	33·11	3	7	40·20	−0·20
7 595	7 606	16·60	36·37	3	7	39·79	+0·21
*7 641	(3 669)	45·98	07·48	3	5	39·98	+0·02
*7 641	(3 670)	45·98	10·08	3	5	40·36	−0·36

Indiscriminate mean = 38° 46' 40''·03.
Weighted mean = 38 46 40 ·00 ± 0''·05.
$e = \pm 0''·60$.

64 observations, 20 pairs. Four observations were rejected at this station.
[Reduction to geodetic station, Cape Henlopen Light — 0''·56.]

I. EASTERN SHORE SERIES—continued.

(3) *Latitude at Dover, Delaware.* C. H. Sinclair. Zenith telescope No. 6. May 17–22, 1897. One division of level = 2″·207, the mean of the observed values of January, 1893, and May, 1895. One turn of micrometer = 76″·237, derived from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
4 538	*2 125	26·67	48·61	4	9	39 09 14·01	−0·39
*2 125	4 607	48·61	21·73	4	9	13·33	+0·29
4 645	4 659	46·24	45·40	3	13	13·56	+0·06
(1 177)	4 689	24·50	31·72	4	15	14·00	−0·38
4 718	4 713	06·51	21·74	4	7	13·46	+0·16
4 728	4 747	51·44	55·36	4	14	13·88	−0·26
2 233	4 789	42·81	23·40	4	15	13·93	−0·31
4 810	(1 208)	11·41	53·22	4	13	13·71	−0·09
*4 847	4 874	24·50	57·03	4	13	13·57	+0·05
*4 847	2 285	24·50	57·23	4	11	13·71	−0·09
4 906	4 958	19·52	11·66	4	17	13·72	−0·10
4 978	2 339	56·51	18·20	4	12	13·31	+0·31
5 075	(1 277)	25·46	37·47	4	12	13·12	+0·50
2 396	*5 130	41·14	04·08	4	10	13·60	+0·02
*5 130	5 178	04·08	47·09	4	13	14·14	−0·52
5 234	(1 316)	25·52	56·67	4	15	12·83	+0·79
2 472	5 307	40·28	27·95	4	12	13·49	+0·13

Indiscriminate mean = 39° 09′ 13″·61.
Weighted mean = 39 09 13 ·62 ± 0″·06.
$e = \pm 0''·41$.
67 observations, 17 pairs.
[Reduction to geodetic station, Court-house Cupola + 0″·52.]

I. EASTERN SHORE SERIES—continued.

(4) *Latitude at Principio, Maryland.* R. D. Cutts. Zenith telescope No. 5. July 19–September 10, 1866. One division of level = 0″·76. One turn of micrometer = 41″·40.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 596	5 652	29·96	13·69	7	13	39 35 32·44	+0·37
5 702	5 717	59·95	21·30	6	13	33·45	−0·64
5 785	5 860	09·40	54·57	6	13	31·88	+0·93
5 900	5 918	09·53	07·47	6	13	32·98	−0·17
6 021	6 091	56·05	39·57	7	13	32·74	+0·07
6 116	6 184	32·00	47·00	6	13	33·02	−0·21
6 232	6 252	23·95	19·38	6	13	32·49	+0·32
6 289	6 387	34·37	46·44	7	13	32·92	−0·11
6 438	6 500	01·94	32·08	6	13	32·11	+0·70
6 581	6 624	57·98	06·89	7	13	32·96	−0·15
6 656	6 667	16·73	58·08	8	14	32·76	+0·05
6 695	6 712	14·65	04·00	5	12	32·46	+0·35
6 731	6 777	58·86	44·71	6	13	33·39	−0·58
6 819	6 834	12·00	07·76	4	11	32·34	+0·47
6 912	6 924	11·94	43·21	6	13	32·39	+0·42
5 911	5 962	34·02	47·85	2	8	33·00	−0·19
6 079	6 134	19·16	27·20	8	14	33·67	−0·86
6 162	6 235	11·56	38·80	4	11	33·53	−0·72
6 348	6 453	21·93	20·27	3	10	33·22	−0·41
6 491	6 520	31·90	12·86	4	11	33·28	−0·47
6 551	6 637	30·00	32·78	4	11	32·40	+0·41
6 698	6 754	48·61	29·45	5	12	32·55	+0·26
6 794	6 861	31·64	51·88	4	11	32·62	+0·19
6 890	6 930	31·90	43·48	5	12	32·99	−0·18
6 996	7 008	03·06	05·62	7	13	33·19	−0·38
7 061	7 101	54·44	59·74	8	14	33·26	−0·45
7 143	7 166	08·00	59·58	9	14	32·61	+0·20
7 204	7 233	48·72	54·07	8	14	32·77	+0·04
7 260	7 313	20·45	05·95	8	14	32·64	+0·17
7 401	7 437	53·48	57·76	8	14	32·00	+0·81
7 461	7 468	23·60	56·93	6	13	32·67	+0·14
7 524	7 559	06·16	00·90	8	14	32·33	+0·48
7 712	7 738	54·04	15·69	9	14	33·00	−0·19
7 798	7 815	35·83	29·68	9	14	32·86	−0·05
7 855	7 923	20·45	43·26	6	13	32·62	+0·19
7 945	8 024	19·22	49·37	6	13	32·64	+0·17
8 083	8 131	15·17	32·85	6	13	32·74	+0·07
8 162	8 227	09·30	27·76	7	13	33·36	−0·55
8 256	8 307	49·28	22·16	5	12	33·00	−0·19
8 359	8	30·41	56·44	4	11	33·28	−0·47

Indiscriminate mean = 39° 35′ 32″·81.
Weighted mean = 39 35 32 ·81 ± 0″·04.
$e = \pm 0''{\cdot}36$.

246 observations, 40 pairs.

[Reduction to geodetic station 0″·00.]

I. EASTERN SHORE SERIES—continued.

(5) *Latitude at Pooles Island, Maryland.* G. Davidson. Zenith telescope M. A. June 13–July 4, 1847. One division of level = 1″·28. One turn of micrometer = 44″·994, derived from latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
*4 706	4 726	51·79	34·02	3	0·7	39 17 17·57	−0·05
*4 706	4 756	51·79	35·47	1	0·4	16·00	+1·52
*4 706	4 789	51·79	24·16	4	0·8	20·06	−2·54
4 874	4 933	04·85	33·95	5	1·8	17·38	+0·14
4 962	*5 064	01·12	47·87	2	0·7	17·59	−0·07
4 969	*5 064	10·10	47·87	5	1·2	16·85	+0·67
5 085	5 116	48·05	38·64	3	1·4	16·56	+0·96
5 348	5 466	28·79	01·48	6	1·9	19·74	−2·22
5 530	5 629	15·59	37·05	6	1·9	17·95	−0·43
*5 647	5 740	01·18	51·69	8	1·3	18·29	−0·77
*5 647	5 745	01·18	40·10	8	1·3	18·48	−0·96
5 797	5 900	48·16	05·33	6	1·9	17·50	+0·02
5 922	5 937	12·42	59·60	7	1·9	16·03	+1·49
6 021	6 052	09·64	48·80	7	1·9	16·02	+1·50
6 134	6 184	27·41	59·32	3	1·4	16·72	+0·80
6 216	6 231	45·00	55·88	7	1·9	18·96	−1·44
6 322	*6 368	35·83	38·30	4	1·1	16·13	+1·39
6 341	*6 368	51·33	38·30	5	1·2	16·66	+0·86
6 397	6 410	04·52	47·11	5	1·8	18·21	−0·69
6 438	6 477	19·00	22·61	6	1·9	17·31	+0·21
6 574	6 496	57·93	11·60	6	1·9	18·30	−0·78
6 582	6 601	53·53	26·37	6	1·9	15·48	+2·04
6 589	6 640	33·10	33·79	5	1·8	17·67	−0·15
6 681	6 695	46·25	32·60	4	1·6	17·89	−0·37
*6 748	6 827	58·83	58·38	4	1·1	17·09	+0·43
*6 748	6 835	58·83	41·09	4	1·1	18·83	−1·31

Indiscriminate mean = 39° 17′ 17″·51.
Weighted mean = 39 17 17 ·52 ± 0″·15.
$e = \pm 1''\cdot01$.
130 observations, 26 pairs.
[Reduction to geodetic station — 7″·84.]

I. EASTERN SHORE SERIES—continued.

(6) *Latitude at Calvert. Maryland.* A. T. Mosman. Meridian telescope No. 7. July 26–August 13, 1871. One division of level = 1″·06. One turn of micrometer = 77″·109, the mean result from observations at four stations.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 821	5 840	38·73	42·08	8	4	38 21 31·30	+0·58
5 874	5 886	50·15	59·76	7	4	33·36	−1·48
5 962	5 990	00·60	25·96	7	4	33·00	−1·12
6 021	6 056	07·35	12·00	7	4	32·03	−0·15
6 068	6 082	60·28	50·54	7	4	31·98	−0·10
6 089	6 122	16·48	60·89	6	4	31·58	+0·30
6 157	6 184	13·50	43·58	1	2	31·96	−0·08
6 218	6 235	47·59	31·85	7	4	30·79	+1·09
6 300	6 350	03·55	52·92	8	4	31·39	+0·49
6 355	6 365	05·80	05·68	7	4	31·28	+0·60
6 390	6 456	47·19	16·90	7	4	32·42	−0·54
6 391	6 466	14·50	48·63	6	4	31·36	+0·52
6 508	6 528	38·14	34·20	6	4	32·18	−0·30
6 586	6 595	15·06	06·86	7	4	32·02	−0·14
6 644	6 662	47·98	01·80	6	4	32·05	−0·17
6 676	6 697	45·48	39·11	6	4	31·40	+0·48
6 701	6 735	35·11	29·88	6	4	29·76	+2·12
6 780	6 794	24·18	46·35	6	4	31·57	+0·31
6 834	6 853	21·21	23·41	6	4	31·36	+0·52
6 879	6 895	04·18	11·79	6	4	32·71	−0·83
6 937	6 986	18·53	58·62	6	4	32·55	−0·67
6 967	6 996	15·24	08·14	6	4	32·52	−0·64
7 027	7 084	06·34	51·75	6	4	32·66	−0·78

Indiscriminate mean = 38° 21′ 31″·88.
Weighted mean = 38 21 31 ·88 ± 0″·11.
$e = \pm 0''\cdot 64$.
145 observations, 23 pairs.
[Reduction to geodetic station − 0″·02.]

I. EASTERN SHORE SERIES—continued.

(7) *Latitude at Taylor, Maryland.* T. J. Lee. Zenith telescope M. A. May 17–29, 1847. One division of level = 1″·28. One turn of micrometer = 45″·028, derived from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
4 121	4 141	49·50	55·53	5	3	38 59 46·73	−0·65
*4 194	4 212	35·87	20·66	6	2	47·21	−1·13
*4 194	4 260	35·87	41·61	5	2	47·20	−1·12
4 276	4 299	46·10	33·95	6	3	45·62	+0·46
4 329	4 371	54·78	00·15	5	3	46·28	−0·20
4 392	4 468	11·95	47·52	5	3	45·60	+0·48
4 566	*4 649	36·18	02·50	5	2	46·03	+0·05
4 575	*4 649	33·89	02·50	6	2	44·99	+1·09
4 675	4 701	18·30	01·05	4	2	45·55	+0·53
*4 817	4 846	11·72	20·20	5	2	46·30	−0·22
*4 817	4 849	11·72	44·27	6	2	46·61	−0·53
4 933	4 967	33·95	34·22	6	3	46·07	+0·01
4 991	5 064	34·20	47·87	4	2	46·40	−0·32
5 115	5 153	00·84	15·27	6	3	44·91	+1·17
5 234	5 307	56·03	43·14	6	3	47·13	−1·05
5 348	5 426	28·60	07·31	5	3	45·73	+0·35
5 490	5 601	37·18	07·58	6	3	45·58	+0·50

Indiscriminate mean = 38° 59′ 46″·11.
Weighted mean = 38 59 46 ·08 ± 0″·12.
$e = \pm 1''\cdot 22$.
91 observations, 17 pairs.
[Reduction from astronomic to geodetic station − 0″·10.]

(8) *Latitude at Marriott, Maryland.* T. J. Lee. Zenith telescope M. A. June 16–25, 1846. One division of level = 1″·28. One turn of micrometer = 45″·168.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
4 933	4 967	19·99	20·07	3	0·9	38 52 24·26	+0·47
5 097	5 146	33·76	40·40	6	1·0	25·11	−0·38
5 223	5 249	25·98	22·94	5	1·0	23·95	+0·78
5 512	5 620	09·46	57·67	7	1·0	23·96	+0·77
5 769	5 893	28·80	15·98	4	1·0	25·72	−0·99
†6 079	6 110	05·88	42·80	6	1·0	25·57	−0·84
6 142	6 243	50·73	01·10	3	0·9	24·48	+0·25

Indiscriminate mean = 38° 52′ 24″·72.
Weighted mean = 38 52 24 ·73 ± 0″·19.
$e = \pm 0''\cdot 75$.
34 observations, 7 pairs.

†Observations upon pairs 5 972 and 6 035 gave a defective result and were rejected.

I. EASTERN SHORE SERIES—continued.

Latitude at Marriott, Maryland. A. D. Bache and J. Hewston. Zenith telescope No. 1. May 19–June 17, 1849. One division of level = 1''·519. One turn of micrometer = 45''·665.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		"	"			° ' "	"
3 931	3 964	51 ·00	31 ·18	1	3	38 52 24 ·93	+0 ·19
3 981	4 147	00 ·66	46 ·71	5	9	24 ·82	+0 ·30
4 194	4 212	15 ·77	58 ·65	4	8	25 ·50	−0 ·38
4 276	4 299	26 ·14	14 ·81	2	5	26 ·12	−1 ·00
4 303	4 390	32 ·63	48 ·86	3	7	25 ·74	−0 ·62
4 453	4 519	23 ·55	54 ·78	4	8	24 ·20	+0 ·92
4 566	4 649	11 ·77	38 ·48	4	8	25 ·95	−0 ·83
4 684	4 706	01 ·00	26 ·40	5	9	24 ·65	+0 ·47
4 741	4 808	59 ·09	48 ·24	5	9	25 ·05	+0 ·07
4 937	4 969	07 ·33	39 ·00	4	8	24 ·73	+0 ·39
5 061	5 092	59 ·57	18 ·47	4	8	24 ·95	+0 ·17
*5 115	5 120	26 ·29	42 ·28	1	2	23 ·82	+1 ·30
*5 115	5 126	26 ·29	25 ·74	1	2	25 ·92	−0 ·80
5 181	5 192	54 ·58	21 ·34	5	9	25 ·28	−0 ·16
5 249	5 293	56 ·41	58 ·74	5	9	24 ·30	+0 ·82
5 367	5 459	48 ·60	38 ·66	5	9	24 ·67	+0 ·45
5 484	5 497	41 ·69	46 ·25	5	9	25 ·62	−0 ·50
5 549	5 602	17 ·13	19 ·22	6	10	25 ·00	+0 ·12
5 747	5 775	35 ·21	48 ·25	4	8	25 ·20	−0 ·08
5 821	5 840	01 ·02	10 ·00	4	8	24 ·83	+0 ·29
5 871	5 986	31 ·05	50 ·25	4	8	25 ·09	+0 ·03
6 056	6 084	45 ·68	56 ·20	4	8	24 ·73	+0 ·39
6 106	6 184	56 ·22	58 ·04	4	8	25 ·80	−0 ·68
6 238	6 255	53 ·29	08 ·77	4	8	25 ·52	−0 ·40
6 395	6 453	43 ·00	33 ·58	4	8	24 ·57	+0 ·55
6 583	6 589	47 ·12	22 ·00	4	8	25 ·07	+0 ·05
6 623	6 657	30 ·00	23 ·18	4	8	26 ·21	−1 ·09
6 709	6 712	09 ·41	08 ·06	4	8	25 ·37	−0 ·25
6 721	6 740	45 ·14	29 ·39	4	8	24 ·51	+0 ·61
6 794	6 818	57 ·25	36 ·76	3	7	25 ·33	−0 ·21
6 839	6 932	40 ·12	30 ·25	3	7	25 ·62	−0 ·50
6 855	6 970	33 ·75	39 ·63	3	7	25 ·10	+0 ·02
7 117	7 153	16 ·54	10 ·21	3	7	25 ·53	−0 ·41
7 243	7 256	36 ·10	50 ·40	3	7	24 ·58	+0 ·54

Indiscriminate mean = 38° 52′ 25''·13.
Weighted mean = 38 52 25 ·12 ± 0''·06.
$e = \pm 0''·54$.
128 observations, 34 pairs.
[Reduction to geodetic station − 0''·27.]

I. EASTERN SHORE SERIES—completed.

(9) *Latitude at Webb, Maryland.* G. W. Dean. Zenith sector No. 1. October 21 to November 14, 1850. Levels No. 2. One division of levels = 1″·21 (mean).

Stars north of zenith.

Star.	Adopted seconds of mean N. P. D.	n′	Latitude.	v
	″		° ′ ″	″
7 022	15·50	7	39 05 25·50	+0·02
7 171	12·58	9	25·67	−0·15
7 544	18·65	6	24·70	+0·82
7 598	58·50	6	25·34	+0·18
7 679	28·63	6	25·92	−0·40
7 681	18·48	6	25·89	−0·37
7 746	58·45	6	25·66	−0·14
7 800	02·80	6	24·93	+0·59
7 815	16·33	6	25·76	−0·24
7 850	39·02	6	24·72	+0·80
7 855	14·40	6	25·94	−0·42
7 906	19·86	6	25·23	+0·29
7 915	24·05	6	25·60	−0·08
7 962	22·45	6	26·33	−0·81
7 972	01·59	6	25·08	+0·44
8 023	44·38	6	25·85	−0·33
8 028	52·56	6	25·21	+0·31
8 082	44·50	6	25·95	−0·43
8 171	47·21	6	25·96	−0·44
8 212	24·40	6	25·92	−0·40
8 224	14·83	6	25·77	−0·25
8 261	44·10	6	25·48	+0·04
8 345	05·11	5	25·19	+0·33
100	07·90	6	25·59	−0·07
152	21·90	6	25·39	+0·13
227	20·00	6	25·83	−0·31
283	44·50	6	25·63	−0·11
318	30·72	6	24·97	+0·55
441	07·00	6	25·46	+0·06
502	05·00	6	25·69	−0·17
522	09·20	6	25·66	−0·14
555	32·03	6	25·70	−0·18
566	46·50	6	25·03	+0·49
628	34·00	6	26·06	−0·54
676	30·00	6	24·83	+0·69
727	14·86	6	25·57	−0·05
967	54·50	6	25·85	−0·33
1 043	39·10	8	25·28	+0·24
1 071	38·85	5	25·48	+0·04
1 099	41·00	6	25·13	+0·39
1 210	29·45	6	25·12	+0·40
1 266	37·12	6	25·36	+0·16
2 323	55·50	6	25·82	−0·30
1 414	56·29	6	25·96	−0·44
1 613	39·67	7	25·20	+0·32

275 observations, 45 stars.

Mean = 39° 05′ 25″·52 = φ_n.

± 0·04

Stars south of zenith.

Star.	Adopted seconds of mean N. P. D.	n′	Latitude.	v
	″		° ′ ″	″
6 849	32·82	7	39 05 24·75	+0·15
6 915	18·00	7	24·37	+0·53
6 967	01·15	6	25·58	−0·68
7 084	01·23	7	24·10	+0·80
7 313	48·80	6	25·19	−0·29
7 336	07·50	7	24·82	+0·08
7 368	09·15	6	24·60	+0·30
7 398	55·10	6	24·46	+0·44
7 462	58·66	6	25·24	−0·34
7 607	20·13	6	24·56	+0·34
7 765	39·89	6	24·39	+0·51
8 097	06·20	6	25·94	−1·04
8 159	18·40	6	24·12	+0·78
8 284	31·35	6	24·84	+0·06
4	16·10	8	24·71	+0·19
52	04·80	6	25·16	−0·26
155	25·50	6	24·53	+0·37
259	55·20	6	25·36	−0·46
395	32·00	6	25·43	−0·53
465	00·95	6	26·07	−1·17
624	28·40	6	25·02	−0·12
691	27·60	5	24·87	+0·03
861	44·80	6	25·58	−0·68
871	08·50	6	26·03	−1·13
912	29·20	6	25·31	−0·41
941	04·90	6	24·22	+0·68
981	44·45	6	24·16	+0·74
1 017	49·08	5	24·70	+0·20
1 123	31·84	6	25·36	−0·46
1 138	29·00	6	24·58	+0·32
1 207	59·00	6	24·35	+0·55
1 476	55·26	6	25·69	−0·79
1 530	32·25	6	24·88	+0·02
1 681	29·30	7	23·55	+1·35

209 observations, 34 stars.

Mean = 39° 05′ 24″·90 = φ_s.

± 0·07

Adopted latitude = ½ ($\varphi_n + \varphi_s$) = 39° 05′ 25″·21 ± 0″·04.

[Reduction to geodetic station + 0″·25.]

2. ALLEGHENY SERIES.

(10) *Latitude at Hill, Maryland.* G. W. Dean. Zenith sector No. 1. August 23 to September 13, 1850. Levels No. 2. One division of levels = 1″·20 (mean).

Stars north of zenith.

Star.	Adopted seconds of mean N. P. D.	n'	Latitude.	v
	″		° ′ ″	″
5 937	08·50	8	38 53 53·20	−0·58
5 990	41·50	5	53·06	−0·44
6 091	29·52	7	53·04	−0·42
6 218	11·30	6	52·71	−0·09
6 268	17·40	5	53·19	−0·57
6 357	40·90	5	52·37	+0·25
6 928	34·00	6	51·85	+0·77
6 983	40·25	6	51·96	+0·66
7 022	15·50	5	52·69	−0·07
7 171	12·58	6	53·20	−0·58
7 313	48·80	6	52·04	+0·58
7 544	18·65	6	51·92	+0·70
7 598	58·50	4	52·51	+0·11
7 679	28·63	5	52·64	−0·02
7 681	18·48	6	52·83	−0·21
7 765	39·89	5	51·31	+1·31
7 800	02·80	5	52·30	+0·32
7 815	16·33	5	53·46	−0·84
7 850	39·02	5	52·10	+0·52
7 855	14·40	5	53·61	−0·99
7 906	19·86	5	52·05	+0·57
7 915	24·05	5	52·49	+0·13
7 962	22·45	5	53·20	−0·58
7 972	01·59	5	52·31	+0·31
8 023	44·38	5	53·31	−0·69
8 028	52·56	5	52·19	+0·43
8 082	44·50	5	53·52	−0·90
8 171	47·21	5	52·99	−0·37
8 212	24·40	5	52·84	−0·22
8 224	14·83	5	52·43	+0·19
8 261	44·10	5	52·21	+0·41
8 345	05·11	5	52·26	+0·36

171 observations, 32 stars.

Mean = 38° 53′ 52″·62 = φ_n.
± 0·07

Stars south of zenith.

Star.	Adopted seconds of mean N. P. D.	n'	Latitude.	v
	″		° ′ ″	″
5 986	52·50	3	38 53 51·72	+0·27
6 084	58·00	5	51·24	+0·75
6 147	21·98	5	52·40	−0·41
6 150	16·44	6	52·42	−0·43
6 238	51·90	6	52·00	−0·01
6 355	11·20	8	51·97	+0·02
6 429	30·00	8	51·54	+0·45
6 497	40·28	6	51·85	+0·14
6 556	55·45	5	51·99	0·00
6 571	48·35	6	52·13	−0·14
6 599	50·20	5	52·11	−0·12
6 657	15·94	6	52·34	−0·35
6 667	47·90	6	52·44	−0·45
6 740	21·40	6	51·20	+0·79
6 784	05·73	6	52·40	−0·41
6 849	32·82	4	52·52	−0·53
6 851	45·00	6	51·52	+0·47
6 915	18·00	5	51·78	+0·21
6 967	01·15	5	52·82	−0·83
7 061	59·20	6	32·14	−0·15
7 084	01·23	5	51·64	+0·35
7 152	18·45	6	51·43	+0·56
7 336	07·50	6	51·57	+0·42
7 368	09·15	7	51·99	0·00
7 398	55·10	5	52·04	−0·05
7 462	58·66	5	52·59	−0·60
7 607	20·13	6	51·20	+0·79
8 097	06·20	5	53·06	−1·07
8 159	18·40	5	51·27	+0·72
8 284	31·35	5	52·38	−0·39

168 observations, 30 stars.

Mean = 38° 53′ 51″·99 = φ_s.
± 0·06

Adopted latitude = ½ ($\varphi_n + \varphi_s$) = 38° 53′ 52″·31 ± 0″·05.

[Reduction to geodetic station + 0″·53.]

2. ALLEGHENY SERIES—continued.

(11) *Latitude at Soper, Maryland.* G. W. Dean. Zenith sector No. 1. June 29 to July 25, 1850. Levels No. 2. One division of levels = 1″·21 (mean).

Stars north of zenith.

Star.	Adopted seconds of mean N. P. D.	n′	Latitude.	v
	″		° ′ ″	″
4 607	11·45	5	39 05 12·18	−0·97
4 741	15·70	3	11·93	−0·72
4 937	21·71	3	9·36	+1·85
5 092	31·31	4	11·36	−0·15
5 181	07·50	3	12·40	−1·19
5 497	54·63	4	11·48	−0·27
5 549	24·66	3	12·18	−0·97
5 775	52·64	6	11·67	−0·46
5 871	34·80	3	10·34	+0·87
5 937	08·50	3	11·35	−0·14
5 990	41·50	3	10·21	+1·00
6 056	47·20	4	12·01	−0·80
6 091	29·52	5	12·18	−0·97
6 255	07·20	4	10·80	+0·41
6 623	23·25	4	11·83	−0·62
6 721	36·61	3	10·13	+1·08
6 928	34·00	3	10·87	+0·34
6 983	40·25	5	11·29	−0·08
7 076	40·37	4	10·98	+0·23
7 153	57·78	3	11·57	−0·36
7 171	12·58	3	11·37	−0·16
7 243	22·61	4	9·14	+2·07

82 observations, 22 stars.
Mean = 39° 05′ 11″·21 = φ_n.
± 0 ·14.

Stars south of zenith.

Star.	Adopted seconds of mean N. P. D.	n′	Latitude.	v
	″		° ′ ″	″
4 808	04·00	5	39 05 09·59	+0·57
4 876	26·50	6	09·86	+0·30
4 969	53·15	3	08·93	+1·23
5 061	12·92	4	09·91	+0·25
5 143	38·60	4	10·46	−0·30
5 192	32·40	4	09·88	+0·28
5 484	49·42	3	08·86	+1·30
5 602	26·80	5	09·97	+0·19
5 747	41·10	4	11·50	−1·34
5 834	08·50	3	09·63	+0·53
5 886	45·14	4	11·48	−1·32
5 986	52·50	3	10·67	−0·51
6 084	58·00	3	08·94	+1·22
6 238	52·37	3	11·82	−1·66
6 355	11·20	6	10·30	−0·14
6 429	30·00	6	10·71	−0·55
6 497	40·28	4	09·90	+0·26
6 571	48·35	4	11·48	−1·32
6 657	15·94	3	10·52	−0·36
6 673	07·44	5	09·74	+0·42
6 740	21·40	3	10·32	−0·16
6 784	05·73	5	09·91	+0·25
6 851	45·00	4	09·23	+0·93
7 117	04·36	3	10·72	−0·56
7 204	20·70	3	09·90	+0·26
7 256	37·00	3	10·02	+0·14
7 336	07·50	4	09·43	+0·73
7 368	09·15	5	10·88	−0·72

112 observations, 28 stars.
Mean = 39° 05′ 10″·16 = φ_s.
± 0 ·11.

Adopted latitude = $\frac{1}{2}$ ($\varphi_n + \varphi_s$) = 39° 05′ 10″·69 ± 0″·09.
[Reduction to geodetic station − 0″·10.]

2. ALLEGHENY SERIES—continued.

(12) *Latitude at Seaton, District of Columbia.* L. F. Pourtales. Zenith telescope No. 5. June 24–29, 1850. One division of level = 1″·25. One turn of micrometer = 41″·44.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w′	Latitude.	v
		″	″			° ′ ″	″
4 937	4 969	21·71	52·73	1	2	38 53 23·99	+1·21
5 061	5 092	12·14	30·78	1	2	24·05	+1·15
5 115	5 120	38·53	52·73	1	2	25·39	−0·19
5 181	5 192	06·47	34·60	2	4	25·98	−0·78
5 249	5 293	08·36	07·43	2	4	23·97	+1·23
5 367	5 459	59·70	47·76	1	2	26·21	−1·01
5 549	5 602	24·52	26·36	1	2	25·45	−0·25
5 747	5 775	40·60	52·64	1	2	25·86	−0·66
5 821	5 840	05·00	14·33	1	2	24·94	+0·26
5 871	5 986	34·80	52·50	2	4	25·05	+0·15
6 056	6 084	47·22	58·72	2	4	26·60	−1·40
6 106	6 184	56·59	57·38	1	2	25·11	+0·09
6 238	6 255	51·90	07·20	2	4	26·37	−1·17
6 395	6 453	39·50	29·30	2	4	24·88	+0·32
6 623	6 657	23·50	15·94	2	4	24·98	+0·22
6 794	6 818	51·85	27·83	2	4	24·09	+1·11

Indiscriminate mean = 38° 53′ 25″·18.
Weighted mean = 38 53 25 ·20 ± 0″·15.
$e = \pm 0''\cdot 65$.

24 observations, 16 pairs.
[Reduction to geodetic station 0″·00.]

2. ALLEGHENY SERIES—continued.

(13) *Latitude at Washington, District of Columbia* (Coast and Geodetic Survey Office). E. G. Fischer. Meridian telescope No. 9. July 30 to September 1, 1891. One division of level = 1″·509, determined at this station, July, 1891. One turn of micrometer = 100″·686 from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w'	Latitude.	v
		″	″			° ′ ″	″
5 575M	5 597	23 ·66	50 ·59	6	14	38 53 07 ·28	+0 ·23
5 619	(2 617)	36 ·12	56 ·97	6	14	08 ·35	−0 ·84
5 740	5 765	55 ·34	32 ·81	6	14	07 ·98	−0 ·47
(2 685)	5 834	10 ·60	04 ·36	6	14	07 ·14	+0 ·37
5 874	5 886M	06 ·32	11 ·64	6	14	07 ·90	−0 ·39
5 918	(2 761)	24 ·79	20 ·59	6	14	07 ·81	−0 ·30
(2 793)	6 033	45 ·20	26 ·06	6	14	07 ·43	+0 ·08
6 073	6 091	56 ·47	53 ·58	7	15	07 ·86	−0 ·35
6 109	(2 874)	37 ·14	43 ·84	5	14	07 ·01	+0 ·50
(2 883)	(2 898)	34 ·78	51 ·86	1	8	06 ·92	+0 ·59
(2 888)	(2 898)	19 ·76	51 ·86	4	13	07 ·36	+0 ·15
6 238	6 255	53 ·51	00 ·72	7	15	07 ·73	−0 ·22
6 297	(2 976)	13 ·50	49 ·29	5	14	06 ·75	+0 ·76
6 404	6 466	31 ·69	22 ·66	5	14	07 ·40	+0 ·11
6 574	6 583	44 ·30	35 ·17	6	14	07 ·72	−0 ·21
6 615	6 662	34 ·86	43 ·42	6	14	07 ·77	−0 ·26
6 690	(3 190)	08 ·51	36 ·80	5	14	07 ·41	+0 ·10
6 771	6 817	31 ·30	39 ·17	5	14	07 ·60	−0 ·09
6 876	(3 321)	30 ·59	24 ·39	4	13	07 ·48	+0 ·03
(3 338)	6 976	55 ·45	56 ·49	5	14	07 ·05	+0 ·46

Indiscriminate mean = 38° 53′ 07″·50.
Weighted mean = 38 53 07 ·51 ± 0″·06.
$e = \pm 0''{\cdot}27$.
107 observations, 20 pairs.

NOTE.—Station in yard south of main building; it is 1″·34 south and 1″·14 west of the flagstaff on office building.

2. ALLEGHENY SERIES—continued.

Latitude at Washington, District of Columbia (Coast and Geodetic Survey Office). E. G. Fischer. Meridian telescope No. 9. July 25 to August 12, 1892. One division of level = 1″·483, determined at office July, 1892. One turn of micrometer = 100″·655 from latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 574	5 597	58·22	57·74	4	16	38 53 07·77	−0·31
5 619	(2 617)	42·93	03·70	5	17	07·59	−0·13
5 740	5 765	00·87	37·99	6	18	07·73	−0·27
(2 685)	5 834	15·27	08·60	6	18	07·02	+0·44
5 874	5 886$_{M}$	10·06	15·12	6	18	07·45	+0·01
5 918	(2 761)	27·86	53·42	7	18	07·92	−0·46
(2 793)	6 033	47·08	27·48	7	18	07·05	+0·41
6 073	6 091	57·26	54·13	7	18	08·06	−0·60
6 109	(2 874)	37·47	43·71	5	17	07·21	+0·25
(2 888)	(2 898)	19·21	51·12	5	16	07·38	+0·08
6 238	6 255	52·00	59·05	6	18	07·51	−0·05
6 297	(2 976)	11·52	46·71	6	18	07·36	+0·10
6 404	6 466	27·99	18·26	6	18	06·58	+0·85
6 574	6 583	38·46	29·13	6	18	07·66	−0·20
6 615	6 662	28·44	36·52	6	18	07·78	−0·32
6 690	(3 190)	01·15	29·23	6	18	07·14	+0·32
6 771	6 817	22·76	30·18	4	16	07·73	−0·27
6 876	(3 321)	20·90	14·34	4	16	07·56	−0·10
(3 338)	6 976	44·99	45·58	5	17	07·26	+0·20

Indiscriminate mean = 38° 53′ 07″·46.
Weighted mean = 38° 53′ 07″·46 ± 0″·06.
$e = \pm 0''{\cdot}28$.
107 observations, 19 pairs.

NOTE—Station in yard south of main building; it is 1″·34 south and 1″·14 west of the flagstaff on office building.

2. ALLEGHENY SERIES—continued.

Latitude at Washington, District of Columbia (Coast and Geodetic Survey Office). E. G. Fischer. Zenith telescope No. 4. August 1-22, 1894. One division of level = { 1″·547 (upper) / 1″·342 (lower) }, determined at office May, 1891. One turn of micrometer = 44″·655 from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 574	5 597	12 ·92	12 ·02	7	30	38 53 07 ·43	−0 ·12
5 619	(2 617)	56 ·54	17 ·16	7	26	07 ·62	−0 ·31
5 740	5 765	11 ·93	48 ·34	8	41	07 ·35	−0 ·04
(2 685)	5 834	24 ·61	17 ·07	8	41	06 ·93	+0 ·38
5 874	5 886$_M$	17 ·52	22 ·06	8	25	07 ·53	−0 ·22
5 918	(2 761)	34 ·01	59 ·07	6	25	07 ·76	−0 ·45
(2 793)	6 033	50 ·83	30 ·29	8	39	07 ·15	+0 ·16
6 073	6 091	58 ·82	55 ·22	7	41	07 ·31	0 ·00
6 109	(2 874)	38 ·13	43 ·45	7	30	07 ·14	+0 ·17
(2 888)	(2 898)	18 ·10	49 ·64	4	17	06 ·97	+0 ·34
6 238	6 255	48 ·97	55 ·68	6	29	07 ·04	+0 ·27
6 297	(2 976)	07 ·58	41 ·54	6	39	07 ·48	−0 ·17
6 404	6 466	20 ·60	09 ·43	5	33	07 ·41	−0 ·10
6 574	6 583	26 ·77	17 ·04	5	33	07 ·19	+0 ·12
6 615	6 662	15 ·59	22 ·72	4	36	07 ·59	−0 ·28
6 690	(3 190)	46 ·42	14 ·06	5	38	06 ·97	+0 ·34
6 771	6 817	05 ·67	12 ·19	5	28	07 ·41	−0 ·10
6 876	(3 321)	01 ·52	54 ·22	5	20	07 ·48	−0 ·17
(3 338)	6 976	24 ·05	23 ·74	4	24	07 ·33	−0 ·02

Indiscriminate mean = 38° 53′ 07″·32.
Weighted mean = 38° 53′ 07″·31 ± 0″·04.
$e = \pm$ 0″·16.
115 observations, 19 pairs.

NOTE—Station in yard south of main building; it is 1″·34 south and 1″·14 west of the flagstaff on office building.

Station No. 14. Naval Observatory, old site, Washington, District of Columbia. Results referred to center of dome of central building.

	° ′ ″ ″
1861 to 1864[a] S. Newcomb*	38 53 38 ·78 ± 0 ·10
1883[b] A. Hall	38 ·94 ± 0 ·06
1866–1888[c] J. R. Eastman	38 ·70 ± 0 ·05
1893[d] S. J. Brown	38 ·80 ± 0 ·05
Adopted value	38 ·79 ± 0 ·03

*[a] Observations with Mural Circle. Appendix to Washington Astronomical Observations of 1864.

[b] Observations with Zenith Telescope. Astronomische Nachrichten No. 2625.

[c] Observations with Transit Circle. Letter of Prof. W. Harkness, astronomical director of (new) Observatory, dated June 11, 1898.

[d] Observations with Zenith Telescope. Astronomische Nachrichten, vol. 133, pp. 303-304.

2. ALLEGHENY SERIES—continued.

Station No. 15. United States Naval Observatory, new site, Georgetown Heights, Washington District of Columbia. Results referred to center of clock room.

	° ′ ″ ″
1893–94–95–96[a] W. Harkness and G. A. Hill	38 55 13 ·70 ± 0 ·10
1897[b] O. B. French	13 ·93 ± 0 ·06
Same corrected for motion of pole	13 ·77 ± 0 ·06
Adopted value	13 ·75 ± 0 ·06

Differential measures between the observatories, old and new sites, in 1893, May, by J. R. Eastman and A. N. Skinner, as given in "Astronomy and Astro-Physics, Vol. XII, 1893, pp. 699–701," do not agree sufficiently well with the above absolute values and need further explanation.

(15) *Latitude of Washington, District of Columbia (New Naval Observatory).* O. B. French. Zenith telescope No. 4. June 12–22, 1897. One division of level = 1″·600 upper level, 1″·364 lower level. One turn of micrometer = 44″·630 from observations on circumpolars at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
(2 058)	4 440	59 ·17	15 ·28	2	11	38 55 09 ·80	−0 ·99
*4 513	*4 550	54 ·26	11 ·06	2	5	08 ·00	+0 ·81
*4 513	*4 555	54 ·26	55 ·04	2	5	08 ·12	+0 ·69
*4 526	*4 550	05 ·92	11 ·06	6	4	08 ·97	−0 ·16
*4 526	*4 555	05 ·92	55 ·04	6	4	09 ·10	−0 ·29
4 577	*(2 158)	27 ·25	32 ·50	6	8	08 ·83	−0 ·02
*(2 158)	4 646	32 ·50	04 ·77	6	8	08 ·72	+0 ·09
(2 195)	4 688	57 ·37	00 ·39	5	12	09 ·11	−0 ·29
4 706	4 726	13 ·82	42 ·51	5	12	08 ·25	+0 ·56
4 742	(2 233)	28 ·05	42 ·81	5	12	08 ·50	+0 ·31
(2 254)	4 847	13 ·96	24 ·50	5	12	08 ·93	−0 ·12
4 876	4 937	29 ·74	01 ·19	5	12	08 ·92	−0 ·11
4 958	(2 341)	11 ·66	52 ·04	5	12	08 ·83	−0 ·02
(2 350)	5 026	33 ·95	58 ·42	5	9	09 ·15	−0 ·34
(2 361)	(2 365)	17 ·76	10 ·49	5	5	09 ·35	−0 ·54
5 076	5 084	03 ·63	42 ·34	5	12	08 ·64	+0 ·17
5 115	5 153	28 ·21	23 ·73	5	12	08 ·87	−0 ·06
5 168	5 178$_p$	41 ·01	47 ·09	5	12	08 ·62	+0 ·19
5 249	5 293	55 ·91	26 ·35	5	12	08 ·50	+0 ·31
5 313	5 322	33 ·03	34 ·68	5	12	09 ·22	−0 ·41
5 344	(2 537)	06 ·70	41 ·61	5	12	08 ·44	+0 ·37

Indiscriminate mean = 38° 55′ 08″·80.
Weighted mean = 38 55 08 ·81 ± 0″·06.
$e = \pm 0''\cdot 20$.
100 observations, 21 pairs.
[Reduction to clock room — 5″·12.]

[a] Observations with Prime Vertical Transit and Zenith Telescope. Astronomical Journal No. 404, June, 1897.

In a letter from the astronomical director of the Observatory, Prof. W. Harkness, dated March 6, 1899, the result of the series when extended to 1897·6 is stated to be 38° 55′ 13″·966, with the explanatory remark that the great part of this apparent increase is on account of a change from Professor Boss's system of declination of stars to Professor Newcomb's system as adopted in his new catalogue of fundamental stars; the difference arising from this source being + 0″·305. [N. B.--The new catalogue referred to has not yet been distributed.]

[b] Observations with Zenith Telescope. See abstract of results next page.

2. ALLEGHENY SERIES—continued.

(16) *Latitude at Causten, District of Columbia.* G. W. Dean. Zenith sector No. 1. May 6 to June 13, 1851. Levels No. 2. One division of levels = 1″·21 (mean).

Stars north of zenith.

Star.	Adopted seconds of mean N. P. D.	n′	Latitude.			v
	″		°	′	″	″
3 729	05·11	6	38	55	33·20	−0·38
3 812	38·83	6			32·29	+0·53
3 856	52·20	6			32·08	+0·74
3 952	55·25	6			32·55	+0·27
3 981	40·55	6			33·29	−0·47
4 057	39·73	6			32·60	+0·22
4 235	55·23	5			32·78	+0·04
4 258	17·10	4			32·23	+0·59
4 285	38·45	5			32·58	+0·24
4 346	33·20	5			32·63	+0·19
4 519	32·47	6			32·85	−0·03
4 596	43·80	5			32·55	+0·27
4 607	29·50	6			32·41	+0·41
4 701	10·20	4			32·30	+0·52
4 726	42·52	5			32·93	−0·11
4 741	32·54	4			32·50	+0·32
4 789	31·51	4			33·49	−0·67
4 812	16·03	6			32·20	+0·62
4 827	31·84	5			32·29	+0·53
4 843	00·71	6			33·05	−0·23
4 937	37·25	4			32·53	+0·29
4 958	09·50	5			32·92	−0·10
5 033	16·39	5			33·11	−0·29
5 210	01·47	6			33·02	−0·20
5 298	52·01	4			32·11	+0·71
5 338	50·45	6			33·29	−0·47
5 400	49·02	5			32·88	−0·06
5 463	46·30	5			32·67	+0·15
5 523	16·00	5			33·07	−0·25
5 552	10·63	5			32·39	+0·43
5 596	40·85	5			33·16	−0·34
5 617	29·65	5			32·27	+0·55
5 667	17·30	5			33·41	−0·59
5 775	57·82	5			33·40	−0·58
5 871	38·53	6			33·08	−0·26
5 911	45·86	5			32·92	−0·10
5 937	11·15	7			33·31	−0·49
5 990	43·63	6			32·96	−0·14
6 052	54·09	5			33·44	−0·62
6 091	30·14	7			33·72	−0·90
6 129	25·90	5			33·07	−0·25
6 218	10·15	5			33·10	−0·28
6 255	05·55	6			32·59	+0·23

228 observations, 43 stars.

Mean = 38° 55′ 32″·82 = ϕ_n.
±0 ·04

Stars south of zenith.

Star.	Adopted seconds of mean N. P. D.	n′	Latitude.			v
	″		°	′	″	″
4 010	46·00	5	38	55	31·04	+0·50
4 209	59·83	6			30·86	+0·68
4 311	16·60	4			32·46	−0·92
4 384	09·50	5			31·37	+0·17
4 421	55·42	5			31·62	−0·08
4 876	41·94	6			31·37	+0·17
4 902	52·12	5			31·66	−0·12
4 969	07·40	5			31·13	+0·41
4 991	30·20	4			30·70	+0·84
5 036	36·00	5			31·89	−0·35
5 075	17·48	5			31·06	+0·48
5 084	51·50	5			32·15	−0·61
5 143	51·00	7			31·63	−0·09
5 302	15·40	5			31·02	+0·52
5 432	39·86	5			32·16	−0·62
5 479	49·81	5			31·93	−0·39
5 480	49·32	5			30·94	+0·60
5 604	27·76	5			31·92	−0·38
5 693	55·13	6			30·84	+0·70
5 731	03·38	5			31·50	+0·04
5 747	46·15	4			32·34	−0·80
5 922	24·38	4			31·09	+0·45
6 150	16·22	4			32·01	−0·47
6 178	43·05	6			31·39	+0·15
6 235	58·77	4			32·12	−0·58
6 355	07·85	7			31·61	−0·07
6 429	26·01	6			31·64	−0·10

138 observations, 27 stars.

Mean = 38° 55′ 31″·54 = ϕ_s.
±0 ·07

Adopted latitude = ½ ($\phi_n + \phi_s$) = 38° 55′ 32″·18 ± 0″·06.

[Reduction to geodetic station + 0″·34.]

2. ALLEGHENY SERIES—continued.

Station No. 17. The Georgetown College Observatory, Washington, District of Columbia. The latitude is from "Monthly Notices of the Royal Astronomical Society, London, 1850;" see also "Gould's Astronomical Journal, No. 9, p. 69." Director J. Gurley gives 38° 54′ 26″·07. (Dome.)

Station No. 18. Rockville, Montgomery County, Maryland. June, 1891, to July, 1892. E. Smith, observer. Instrument, Zenith telescope No. 4. This was one of the latitude variation stations; the results are published in detail in the Coast and Geodetic Survey Report for 1892, Part 2, pp. 1–51. The total number of individual results for latitude at this station is 1 789. The value adopted for the latitude is 39° 05′ 10″·45, as given in Coast and Geodetic Survey Report for 1893, Part 2, p. 507.

[Reduction to geodetic station Smith + 0″·18.]

(19) *Latitude at Sugar Loaf, Maryland.* F. D. Granger and J. B. Boutelle. Zenith telescope No. 5. October 12–25, 1879. One division of level = 0″·878, from observations at this station. One turn of micrometer = 41″·379, as observed at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 897	6 932	22 ·38	20 ·36	5	4	39 15 49 ·32	+0 ·39
6 959	6 973	59 ·54	21 ·68	5	4	50 ·04	−0 ·33
7 067	7 091	03 ·80	14 ·78	5	4	50 ·47	−0 ·76
7 171	7 204	05 ·14	56 ·20	5	4	48 ·64	+1 ·07
[1 861]	7 246	01 ·99	18 ·92	4	4	50 ·10	−0 ·39
7 277	7 336	53 ·00	41 ·40	5	4	50 ·66	−0 ·95
7 401	7 410	37 ·71	09 ·20	5	4	49 ·77	−0 ·06
7 495	7 520	26 ·31	30 ·21	5	4	49 ·96	−0 ·25
7 542	7 567	48 ·50	14 ·73	5	4	49 ·55	+0 ·16
7 598	7 607	59 ·84	18 ·43	5	4	49 ·32	+0 ·39
7 627	7 637	37 ·17	21 ·36	5	4	50 ·70	−0 ·99
7 705	7 753	26 ·55	30 ·10	5	4	48 ·30	+1 ·41
7 798	7 824	42 ·70	31 ·45	5	3	48 ·61	+1 ·10
7 880	7 915	30 ·32	22 ·50	6	4	49 ·00	+0 ·71
[2 065]	7 975	57 ·77	01 ·54	5	4	49 ·98	−0 ·27
(3 843)	8 076	37 ·65	18 ·97	5	4	50 ·04	−0 ·33
8 118	8 136	12 ·41	40 ·15	5	4	51 ·20	−1 ·49
8 158	8 203	43 ·04	07 ·67	5	4	50 ·55	−0 ·84
8 231	8 256	54 ·17	30 ·87	5	4	49 ·48	+0 ·23
8 316	8 350	19 ·36	29 ·92	5	4	48 ·85	+0 ·86
28	52	57 ·56	24 ·31	5	4	49 ·18	+0 ·53
100	158	29 ·43	59 ·59	5	4	49 ·88	−0 ·17
178	201	04 ·17	30 ·46	5	4	49 ·04	+0 ·67
219	267	31 ·85	43 ·88	5	4	49 ·68	+0 ·03
305	338	18 ·41	30 ·34	5	4	50 ·13	−0 ·42

Indiscriminate mean = 39° 15′ 49″·70.
Weighted mean = 39 15 49 ·71 ± 0″·10.
$e = \pm 0''\!\cdot\!38$.
125 observations, 25 pairs.

[Reduction to geodetic station − 1″·24.]

2. ALLEGHENY SERIES—continued.

(20) *Latitude at Maryland Heights, Maryland.* F. Blake. Zenith telescope No. 5. September 19 to October 24, 1870. One division of level = 0″·92, 1″·00, 1″·06. Two levels broken at station. One turn of micrometer = 41″·40 as determined at the station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 497	6 520	05·12	54·12	7	9	39 20 32·27	−0·17
6 547	6 566	27·73	40·00	7	9	33·00	−0·90
6 574	6 601	45·85	07·20	7	9	31·78	+0·32
6 635	6 657	54·51	13·43	7	9	32·31	−0·21
6 690	6 723	42·34	29·07	6	9	32·36	−0·26
6 806	6 817	58·58	47·06	7	9	31·12	+0·98
6 868	6 932	13·56	53·50	6	9	32·12	−0·02
7 008	7 022	19·93	29·50	7	9	32·15	−0·05
7 062	7 067	48·80	49·88	7	9	32·23	−0·13
7 091	7 152	02·48	12·10	7	9	32·32	−0·22
7 164	7 198	13·32	27·00	6	9	31·93	+0·17
7 277	7 320	55·28	19·60	6	9	32·12	−0·02
7 336	7 383	18·66	30·20	6	9	31·88	+0·22
7 401	7 410	51·64	25·33	6	9	31·83	+0·27
7 461	7 488	21·80	45·13	5	9	32·33	−0·23
7 521	7 524	10·51	01·03	5	9	31·32	+0·78
7 559	7 602	55·89	46·52	6	9	32·65	−0·55
7 718	7 723	35·76	35·83	5	9	32·16	−0·06
7 757	7 824	05·43	17·78	5	9	31·64	+0·46
7 880	7 915	16·27	10·38	5	9	31·85	+0·25
7 997	8 054	39·18	56·97	6	9	32·29	−0·19
8 075	8 146	19·38	00·06	5	9	32·64	−0·54
8 158	8 203	40·61	05·32	6	9	32·65	−0·55
8 231	8 256	53·60	29·59	6	9	32·69	−0·59
8 284	8 307	51·80	02·15	6	9	32·79	−0·69
8 350	83	21·40	25·70	6	9	32·38	−0·28
152	158	44·15	58·38	5	9	31·85	+0·25
168	182	04·30	34·00	5	9	32·24	−0·14
217	244	07·86	55·20	6	9	31·48	+0·62
254	348	18·00	26·61	6	9	32·77	−0·67
394	453	28·58	30·25	6	9	32·53	−0·43
509	572	36·30	40·80	6	9	32·66	−0·56
515	573	21·14	32·02	6	9	32·06	+0·04
628	649	43·86	31·70	6	9	32·59	−0·49
6 626	6 648	14·67	52·12	5	9	31·74	+0·36
6 698	6 731	19·79	30·66	5	9	31·95	+0·15
6 748	6 835	51·10	10·17	5	9	31·60	+0·50
6 856	6 940	18·14	47·34	5	9	32·06	+0·04
6 979	7 035	40·26	44·24	5	9	31·17	+0·93

2. ALLEGHENY SERIES—continued.

(20) *Latitude at Maryland Heights, Maryland, etc.*—Completed.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		"	"			° ′ "	"
7 073	7 100	39·70	02·22	5	9	39 20 32·75	−0·65
7 161	7 204	29·47	55·60	5	9	32·93	−0·83
7 297	7 313	17·69	09·32	4	9	31·67	+0·43
7 377	7 418	51·18	01·40	5	9	31·80	−0·30
7 450	7 495	10·86	48·30	5	9	32·01	+0·09
7 505	7 565	51·50	17·98	5	9	32·61	−0·51
7 606	4 787(*a*)	03·17	59·43	5	9	31·43	+0·67
7 712	7 749	44·74	20·88	5	9	31·47	+0·63
7 7774	909(*a*)	51·95	35·50	5	9	32·35	−0·25
7 871	7 945	50·25	04·04	5	9	31·68	+0·42
[2 065]	7 975	48·25	52·14	5	9	32·16	−0·06
8 079	8 107	15·49	14·63	5	9	31·45	+0·65
8 126	8 141	51·80	58·40	5	9	32·18	−0·08
8 211	8 224	17·02	45·88	5	9	32·62	−0·52
8 299	8 344	05·85	04·11	5	9	31·54	+0·56
8	65	38·34	32·08	5	9	32·18	−0·08
126	223	09·50	42·10	5	9	32·80	−0·70
239	247	21·89	01·99	5	9	31·56	+0·54
335	341	22·18	08·70	5	9	31·10	+1·00
450	500	37·73	17·00	5	9	32·15	−0·05
525	556	06·60	17·16	5	9	32·72	−0·62
614	647	32·64	02·35	5	9	31·30	+0·80
653	657	21·50	35·90	5	9	32·49	−0·39

Indiscriminate mean = 39° 20′ 32″·10.
Weighted mean = 39 20 32 ·10 ± 0″·04.
$e = \pm$ 0″·30.
343 observations, 62 pairs.
[Reduction to geodetic station − 0″·74.]

(*a*) Indicates Armagh catalogue of 1840.

(21) *Latitude at Bull Run, Virginia.* F. Blake. Zenith telescope No. 5. September 29 to October 14, 1871. One division of level = 1″.00 Mean of 3 determinations at Clarks Mountain and this station. One turn of micrometer = 41″·37, from observations on Polaris at this station—3 sets.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		"	"			° ′ "	"
6 779	6 800	59·20	03·42	5	5	38 52 56·14	+0·65
6 858	6 867	23·42	52·93	5	5	56·53	+0·26
6 881	6 944	50·71	16·80	5	5	56·79	0·00
6 990	6 996	01·35	07·88	5	5	57·32	−0·53
7 022	7 061	18·16	56·31	5	5	56·64	+0·15
7 098	7 149	20·27	29·50	5	5	57·20	−0·41

2. ALLEGHENY SERIES—continued.

(21) *Latitude at Bull Run, Virginia, etc.*—Completed.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
*7 256	7 294	54 ·52	17 ·00	5	3	38 52 56 ·57	+0 ·22
*7 398	*7 398	42 ·00	42 ·00	5	3	56 ·64	+0 ·15
7 444	7 468	47 ·00	39 ·70	5	5	56 ·14	+0 ·65
7 505	7 521	35 ·50	53 ·97	5	5	57 ·06	−0 ·27
7 585	7 636	40 ·17	42 ·43	5	5	57 ·63	−0 ·84
7 707	7 742	36 ·36	39 ·38	5	5	55 ·73	+1 ·06
7 757	7 825	47 ·83	12 ·93	5	5	55 ·55	+1 ·24
7 953	7 997	48 ·15	20 ·16	5	5	57 ·94	−1 ·15
8 114	*8 133	21 ·37	18 ·90	5	3	57 ·10	−0 ·31
8 222	8 279	17 ·50	07 ·36	5	5	56 ·92	−0 ·13
8 301	8 317	26 ·50	20 ·06	5	5	57 ·07	−0 ·28
63	*126	56 ·00	49 ·50	5	3	56 ·04	+0 ·75
166	198	43 ·65	19 ·25	5	5	56 ·38	+0 ·41
229	235	32 ·78	52 ·50	5	5	56 ·82	−0 ·03
283	343	56 ·00	45 ·55	5	5	56 ·62	+0 ·17
409	480	32 ·88	26 ·20	5	5	57 ·06	−0 ·27
508	523	32 ·20	34 ·25	5	5	56 ·87	−0 ·08
6 861	6 868	05 ·62	04 ·23	5	5	56 ·32	+0 ·47
6 940	6 959	36 ·84	25 ·31	5	5	56 ·03	+0 ·76
7 001	7 008	55 ·36	08 ·75	5	5	56 ·84	−0 ·05
7 140	7 189	00 ·13	40 ·94	5	5	56 ·84	−0 ·05
*7 256	7 278	54 ·52	58 ·20	5	3	56 ·45	+0 ·34
7 297	7 320	06 ·43	05 ·26	5	5	55 ·67	+1 ·12
7 333	7 399	08 ·48	36 ·43	5	5	57 ·42	−0 ·63
7 455	7 465	36 ·44	15 ·98	5	5	58 ·14	−1 ·35
7 476	7 520	38 ·22	37 ·92	5	5	57 ·98	−1 ·19
7 627	7 676	51 ·40	20 ·76	5	5	56 ·66	+0 ·13
7 733	7 749	18 ·27	03 ·21	5	5	57 ·07	−0 ·28
7 914	7 995	54 ·37	17 ·00	5	5	56 ·44	+0 ·35
8 125	*8 133	56 ·00	18 ·90	5	3	56 ·35	+0 ·44
8 296	8 310	46 ·28	05 ·63	5	5	56 ·92	−0 ·13
102	*126	05 ·37	49 ·50	5	3	58 ·24	−1 ·45
168	218	44 ·80	09 ·30	5	5	56 ·48	+0 ·31
322	391	51 ·96	50 ·33	5	5	56 ·13	+0 ·66
453	535	11 ·82	08 ·00	5	5	57 ·60	−0 ·81

Indiscriminate mean = 38° 52′ 56″·79.
Weighted mean = 38 52 56 ·79 ± 0″·07.
$e = \pm 0''·26$.
205 observations, 41 pairs.
[Reduction to geodetic station − 0″·63.]

2. ALLEGHENY SERIES—continued.

(22) *Latitude at Strasburg, Virginia.* C. H. Sinclair. Meridian telescope No. 13. June 7–22, 1881. One division of level = 2″·69, determined at office, August, 1879. One turn of micrometer = 77″·86, from observations on Polaris at this station—2 sets.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 168	5 178	30·47	37·76	5	7	38 59 32·50	−1·01
5 249	5 293	56·57	37·51	7	9	31·19	+0·30
5 313	5 322	48·99	51·45	7	9	30·90	+0·59
5 348	5 426	59·64	26·48	5	7	31·43	+0·06
5 460	5 496	21·53	03·21	6	8	32·37	−0·88
5 525	5 599	00·36	04·62	7	9	32·34	−0·85
5 619	(2 617)	28·08	50·32	5	7	31·09	+0·40
5 643	(2 636)	18·45	55·76	5	7	31·02	+0·47
5 740	5 765	00·20	40·59	6	8	30·96	+0·53
5 776	(2 716)	53·56	07·24	3	5	30·98	+0·51
5 860	(2 732)	52·15	57·35	6	8	32·35	−0·86
5 918	(2 761)	53·96	23·38	6	8	30·48	+1·01
5 978	5 991	03·13	30·34	5	7	31·68	−0·19
6 047	(2 822)	35·73	22·95	4	6	30·72	+0·77
6 069	6 114	37·77	21·37	2	3	30·44	+1·05
6 109	(2 874)	33·26	45·16	5	7	31·69	−0·20
(2 883)	(2 898)	36·46	58·24	4	6	31·90	−0·41
6 203	6 235	50·22	18·43	5	7	31·52	−0·03
6 238	6 255	08·43	17·39	3	5	31·26	+0·23
6 297	(2 976)	33·20	15·00	4	6	31·92	−0·43
6 355	6 391	34·91	40·70	5	7	31·81	−0·32
(3 023)	6 452	16·40	43·63	1	2	31·27	+0·22

Indiscriminate mean = 38° 59′ 31″·45.
Weighted mean = 38 59 31 ·49 ± 0″·09.
$e = \pm 0''·74$.
106 observations, 22 pairs.
[Reduction to geodetic station + 0″·01.]

2. ALLEGHENY SERIES—continued.

(23) *Latitude at Clark Mountain, Virginia.* F. Blake. Zenith telescope No. 5. July 31 to August 20, 1871. One division of level = 1″·00, from two determinations at this station. One turn of micrometer = 41″·42, from observations upon Polaris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 619	5 644	21·27	47·31	5	6	38 18 38·76	+1·04
5 728	5 749	39·49	13·64	5	6	40·40	−0·60
5 775	5 863	41·64	51·50	5	6	40·39	−0·59
5 937	5 967	08·00	41·26	5	6	40·01	−0·21
6 033	6 052	54·52	14·70	5	6	41·19	−1·39
6 223	6 335	21·15	50·29	5	6	39·88	−0·08
*6 365	*6 365	06·04	06·04	5	3	38·43	+1·37
6 426	6 475	02·52	22·88	5	6	39·88	−0·08
6 496	6 527	20·16	53·07	5	6	40·81	−1·01
6 581	6 599	27·61	40·98	5	6	39·51	+0·29
6 674	6 687	40·28	29·23	5	6	39·69	+0·11
6 698	6 745	12·47	42·27	5	6	40·02	−0·22
*6 765	*6 765	04·12	04·12	5	3	39·19	+0·61
*6 806	*6 806	47·59	47·59	5	3	39·58	+0·22
6 824	6 835	18·31	00·97	5	6	40·37	−0·57
6 856	6 883	08·50	18·20	5	6	40·40	−0·60
6 933	6 976	59·20	35·83	5	6	39·30	+0·50
7 006	7 022	20·73	17·82	5	6	40·18	−0·38
7 098	7 121	20·26	07·01	5	6	39·97	−0·17
7 164	7 171	60·68	46·72	5	6	39·41	+0·39
7 213	7 277	56·21	41·26	5	6	40·18	−0·38
7 313	7 385	56·55	14·07	5	6	39·13	+0·67
7 444	7 448	47·00	48·45	5	6	38·73	+1·07
7 505	7 524	35·30	45·98	5	6	38·88	−0·92
5 975	6 021	18·28	07·62	5	6	39·72	+0·08
6 487	6 555	18·66	57·05	5	6	39·62	+0·18
6 583	6 661	35·26	23·75	5	6	40·03	−0·23
6 691	6 717	14·63	03·66	5	6	40·09	−0·29
6 739	6 818	50·23	19·32	5	6	39·70	+0·10
6 847	6 901	50·53	37·64	5	6	39·99	−0·19
6 952	6 970	36·78	42·53	5	6	39·63	+0·17
6 998	7 041	09·05	59·28	5	6	39·07	+0·73
7 083	7 131	32·65	36·94	5	6	38·67	+1·13
7 149	7 220	29·23	41·71	5	6	40·02	−0·22
7 246	7 294	63·04	18·95	5	6	39·57	+0·23
7 345	7 368	08·03	03·83	5	6	39·82	−0·02
7 465	7 503	17·09	38·95	5	6	40·64	−0·84
7 528	7 545	56·38	37·92	5	6	39·44	+0·36
*7 602	7 602	29·95	29·95	5	3	40·67	−0·87
7 737	7 753	46·27	50·60	5	6	39·55	+0·25
7 798	7 820	06·07	37·72	5	6	39·66	+0·14
7 845	7 923	09·77	09·56	5	6	40·49	−0·69
7 937	7 953	47·37	48·26	5	6	40·44	−0·64
8 032	*8 036	58·57	56·05	5	6	39·38	+0·42

Indiscriminate mean = 38° 18′ 39″·78.
Weighted mean = 38 18 39·80 ± 0″·06.
$e = \pm 0''{\cdot}25$.
220 observations, 44 pairs.
[Reduction to geodetic station − 0″·25.]

2. ALLEGHENY SERIES—continued.

(24) *Latitude at Charlottesville, Virginia.* F. H. Parsons. Transit No. 4. August 11–29, 1882. One division of level = 2″·12, as observed at the office, July, 1881. One turn of micrometer = 41″·34, from observations on δ Ursæ Minoris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 765	5 840	45·78	27·29	4	3	38 01 61·52	−0·57
(2 717)	5 886	02·09	41·60	3	3	60·23	+0·72
5 950	(2 812)	05·91	41·80	6	3	59·90	+1·05
6 068	(2 845)	09·38	03·82	5	3	61·14	0·19
6 106	6 185	10·57	56·40	6	3	60·02	+0·93
6 227	6 302	28·70	07·50	4	3	61·08	−0·13
6 322	6 350	12·89	22·06	5	3	61·71	−0·76
6 335	6 392	31·76	02·03	6	3	62·14	−1·19
(3 015)	6 438	38·23	57·16	6	3	62·18	−1·23
6 475)	6 491	32·37	17·17	8	3	60·82	+0·13
(3 078)	6 583	37·22	29·18	7	3	60·31	+0·64
6 650	6 646	50·78	10·09	4	3	60·67	+0·28
6 674	6 697	23·17	16·27	4	3	61·30	−0·35
6 745	6 784	13·72	46·17	4	3	62·13	−1·18
6 836	6 833	58·30	13·65	3	3	59·86	+1·09
(3 294)	6 876	08·54	57·44	4	3	60·22	+0·73

Indiscriminate mean = 38° 02′ 00″·95.
Weighted mean = 38 02 00 ·95 ± 0″·14.
$e = \pm 0''\cdot 44$.
79 observations, 16 pairs.
[Reduction to dome of university + 10″·25.]

2. ALLEGHENY SERIES—continued.

(25) *Latitude at Long Mount, Virginia.** A. T. Mosman. Zenith telescope No. 2. October 16–22, 1875. One division of level = 1″·06, from observations at Maryland Heights, October to November, 1875. One turn of micrometer = 44″·779, from observations upon circumpolars at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
7 585	7 612	35 ·24	08 ·97	6	6	37 17 29 ·62	−0 ·90
7 641	7 658	57 ·37	10 ·06	6	6	28 ·78	−0 ·06
7 674	7 700	59 ·05	50 ·74	6	6	29 ·29	−0 ·57
7 760	7 788	04 ·57	18 ·10	6	6	28 ·24	+0 ·48
7 796	7 829	26 ·07	25 ·11	6	6	27 ·66	+1 ·06
7 843	7 850	58 ·67	00 ·34	6	6	29 ·53	−0 ·81
7 868	7 881	40 ·00	03 ·80	6	6	28 ·94	−0 ·22
7 902	7 943	54 ·31	02 ·95	6	6	28 ·88	−0 ·16
7 967	7 971	24 ·68	43 ·62	6	6	28 ·83	−0 ·11
7 988	8 039	59 ·94	51 ·70	6	6	29 ·26	−0 ·54
8 070	8 077	59 ·97	10 ·98	6	6	28 ·18	+0 ·54
8 127	8 173	02 ·06	11 ·49	6	6	27 ·85	+0 ·87
8 206	8 223	52 ·60	43 ·64	7	6	28 ·40	+0 ·32
8 256	8 261	49 ·72	25 ·03	7	6	29 ·14	−0 ·42
8 277	8 300	03 ·65	53 ·55	6	6	28 ·23	+0 ·49
8 359	8 370	29 ·53	57 ·26	6	6	28 ·89	−0 ·17
46	82	41 ·70	37 ·80	5	6	28 ·82	−0 ·10
169	214	55 ·00	16 ·74	5	6	28 ·93	−0 ·21
223	244	04 ·34	17 ·51	6	6	27 ·60	+1 ·12
285	318	01 ·55	27 ·98	5	6	29 ·38	−0 ·66

Indiscriminate mean = 37° 17′ 28″·72.
Weighted mean = 37 17 28 ·72 ± 0″·09.
$e = \pm 0''{\cdot}31$.
119 observations, 20 pairs.
[Reduction to geodetic station −0″·02.]

*Practice observations were made at this station by W. B. Fairfield and D. S. Wolcott, aids. Their results were: Fairfield, 29″·00 ± 0″·12; Wolcott, 28″·57 ± 0″·15, mean = 28″·80. In view of the fact that these observers were then inexperienced, this result has not been combined with that given above.

2. ALLEGHENY SERIES—continued.

(26) *Latitude at Elliott Knob, Virginia.* W. B. Fairfield. Zenith telescope No. 6. July 10 to August 2, 1878. One division of level = 1″·09, determined at office April, 1879. One turn of micrometer = 76″·33, from observations upon Polaris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 033	5 072	23 ·98	43 ·28	3	2	38 09 57 ·08	+0 ·43
5 115	5 152	29 ·93	37 ·00	3	2	57 ·03	+0 ·48
5 187	5 279	07 ·01	45 ·60	6	4	57 ·29	+0 ·22
5 298	5 319	41 ·30	37 ·97	7	4	57 ·59	−0 ·08
5 348	5 367	31 ·09	36 ·50	7	4	58 ·16	−0 ·65
5 411	5 460	31 ·50	55 ·35	8	5	57 ·59	−0 ·08
5 496	5 546	37 ·99	22 ·04	6	4	57 ·48	+0 ·03
5 619	5 644	10 ·72	33 ·40	7	4	56 ·20	+1 ·31
5 666	5 706	03 ·20	46 ·53	7	4	57 ·55	−0 ·04
5 728	5 749	19 ·59	51 ·48	6	4	58 ·32	−0 ·81
5 734	5 757	33 ·87	20 ·10	6	4	56 ·63	+0 ·88
5 795	5 828	07 ·85	57 ·01	7	4	58 ·01	−0 ·50
5 887	5 893	52 ·33	07 ·39	6	4	58 ·05	−0 ·54
5 937	5 967	28 ·14	58 ·31	8	5	58 ·07	−0 ·56
6 021	6 056	24 ·84	19 ·89	8	5	55 ·61	+1 ·90
6 089	6 122	20 ·47	02 ·55	7	4	58 ·22	−0 ·71
6 159	6 184	21 ·67	38 ·82	6	4	56 ·61	+0 ·90
6 223	6 335	12 ·56	32 ·38	6	4	57 ·17	+0 ·34
6 300	6 350	49 ·54	34 ·17	7	4	57 ·60	−0 ·09
6 355	6 392	44 ·05	16 ·02	7	4	57 ·35	+0 ·16
6 426	6 475	35 ·30	51 ·57	6	4	57 ·87	−0 ·36
6 482	6 508	21 ·57	04 ·19	6	4	58 ·90	−1 ·39
6 556	6 593	24 ·77	10 ·41	6	4	58 ·19	−0 ·68

Indiscriminate mean = 38° 09′ 57″·50.
Weighted mean = 38 09 57 ·51 ± 0″·11
$e = \pm 0''\cdot 98$.
146 observations, 23 pairs.
[Reduction to geodetic station − 0″·29.]

2. ALLEGHENY SERIES—continued.

(27) *Latitude at Keeney, West Virginia.* A. T. Mosman. Meridian telescope No. 13. August 22 to September 3, 1880. One division of level = 2″·69. One turn of micrometer = 77″·848, from observations on Polaris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 235	6 268	19·59	26·85	6	5	37 46 23·49	−0·23
6 322	6 350	17·66	27·49	6	5	24·18	−0·92
6 341	6 372	26·58	59·14	6	5	22·90	+0·36
6 452	6 453	46·33	21·52	6	5	22·50	+0·76
6 475	6 497	41·43	17·58	6	5	23·35	−0·09
6 520	6 547	04·64	34·56	6	5	22·25	+1·01
6 650	6 646	04·30	23·87	6	5	22·87	+0·39
6 674	6 723	37·42	12·90	4	4	23·19	+0·07
6 734	6 758	22·52	51·84	7	5	22·85	+0·41
6 783	6 847	39·14	26·99	7	5	23·38	−0·12
6 867	6 868	26·10	37·23	6	5	24·31	−1·05
6 915	6 986	26·46	20·92	6	5	24·36	−1·10
(3 383)	7 067	23·87	51·69	6	5	22·70	+0·56
[1 819]	7 143	57·65	14·47	5	4	22·32	+0·94
7 164	7 241	07·62	31·90	5	4	24·36	−1·10
7 306	7 368	54·41	52·76	6	5	22·70	+0·56
7 398	[3 578]	27·97	47·10	5	4	23·36	−0·10
7 468	7 474	19·14	11·07	6	5	23·61	−0·35

Indiscriminate mean = 37° 46′ 23″·26.
Weighted mean = 37 46 23 ·26 ± 0″·11.
$e = \pm 0''.55$.
105 observations, 18 pairs.
[Reduction to geodetic station − 0″·75.]

2. ALLEGHENY SERIES—continued.

(28) *Latitude at Charleston, West Virginia.* F. H. Parsons. Transit No. 6. August 17–21, 1883. One division of level = 1″·6. One turn of micrometer = 44″·191 from observations upon circumpolars.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
(3 322)	6 932	58·86	38·78	2	2	38 21 05·98	+0·41
6 952	6 970	28·52	31·77	3	3	07·26	−0·87
7 022	(3 388)	02·09	03·17	3	3	04·18	+2·21
7 086	7 140	26·77	32·09	3	3	05·51	+0·88
7 164	7 171	29·78	14·36	3	3	07·79	−1·40
7 188	[1 861]	50·99	09·93	3	3	08·24	−1·85
7 241	(3 491)	51·80	24·20	3	3	04·96	+1·43
7 301	7 368	07·81	09·05	3	3	05·51	+0·88
7 385	7 398	12·74	43·24	2	2	05·82	+0·57
7 465	7 503	12·92	30·44	2	2	06·30	+0·09
7 555	7 585	35·05	24·65	1	1	06·38	+0·01
7 598	7 623	53·46	14·08	1	1	06·33	+0·06
7 664	7 700	24·75	31·67	1	1	05·73	+0·66
7 733	7 754	47·91	32·08	1	1	08·30	−1·91
7 778	7 807	22·83	33·57	1	1	05·44	+0·95
7 823	7 896	10·80	50·50	1	1	07·07	−0·68
7 945	[2 064]	59·29	11·88	1	1	08·29	−1·90
7 995	8 032	27·73	06·22	1	1	04·54	+1·85
8 071	8 124	42·71	42·57	1	1	07·65	−1·26
8 141	8 224	42·69	32·78	1	1	07·47	−1·08
8 250	8 273	04·79	35·78	1	1	07·26	−0·87
8 300	(4 057)	12·57	09·90	1	1	08·21	−1·82

Indiscriminate mean = 38° 21′ 06″·56.
Weighted mean = 38 21 06 ·39 ± 0″·19.
$e = \pm$ 1″·00.
39 observations, 22 pairs.
[Reduction to geodetic station 0″·00.]

2. ALLEGHENY SERIES—continued.

*Latitude at Charleston, West Virginia**. C. Schenk. Transit No. 6. August 24–26, 1883. One division of level = 1″·6. One turn of micrometer = 44″·191 from observations upon circumpolars.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
(3 322)	6 932	58·86	38·78	2	5	38 21 07·78	−0·80
6 952	6 970	28·52	31·77	1	3	07·42	−0·44
7 022	(3 388)	02·09	03·17	2	5	07·44	−0·46
7 086	7 140	26·77	32·09	3	6	06·37	+0·61
7 164	7 171	29·78	14·36	1	3	06·41	+0·57
7 241	(3 491)	51·80	24·20	3	6	07·60	−0·62
7 301	7 368	07·81	09·05	3	6	06·13	+0·85
7 465	7 503	12·92	30·44	3	6	07·61	−0·63
7 555	7 585	35·05	24·65	2	5	06·47	+0·51
7 598	7 623	53·46	14·08	3	6	05·70	+1·28
7 664	7 700	24·75	31·67	3	6	07·12	−0·14
7 733	7 754	47·91	32·08	3	6	06·43	+0·55
7 778	7 807	22·83	33·57	3	6	06·48	+0·50
7 823	7 896	10·80	50·50	2	5	06·88	+0·10
7 945	[2 064]	59·29	11·88	3	3	07·47	−0·49
7 995	8 032	27·73	06·22	3	6	06·45	+0·53
8 071	8 124	42·71	42·57	3	6	07·52	−0·54
8 141	8 224	42·69	32·78	2	5	08·18	−1·20
8 250	8 273	04·79	35·78	2	5	07·30	−0·32
8 300	(4 057)	12·57	09·90	2	3	07·64	−0·66

Indiscriminate mean = 38° 21′ 07″·02.
Weighted mean = 38 21 06 ·98 ± 0″·10.
$e = \pm 0''\cdot 54$.
49 observations, 20 pairs.
[Reduction to geodetic station 0″.00.]

* Practice observations were made at this station by W. B. Fairfield and D. S. Wolcott, aids. Their results were: Fairfield, 29″·00 ± 0″·12; Wolcott, 28″·57 ± 0″·15, mean = 28″·80. In view of the fact that these observers were then inexperienced this result has not been combined with that given above.

2. ALLEGHENY SERIES—continued.

*Latitude at Charleston, West Virginia**. C. Terry. Transit No. 6. August 29 to September 6, 1883, One division of level = 1″·6. One turn of micrometer = 44″·191 from observations upon circumpolars.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
7 086	7 140	26·77	32·09	5	3·0	38 21 07·77	−0·87
7 164	7 171	29·78	14·36	4·5	2·9	06·99	−0·09
7 188	[1 861]	50·99	09·93	5	3·0	06·89	+0·01
7 241	(3 491)	51·80	24·20	5	3·0	06·63	+0·27
7 301	7 368	07·81	09·05	5	3·0	05·48	+1·42
7 385	7 398	12·74	43·24	6	3·2	08·10	−1·20
7 465	7 503	12·92	30·44	6	3·2	05·90	+1·00
7 555	7 585	35·05	24·65	6	3·2	07·25	−0·35
7 598	7 623	53·46	14·08	6	3·2	05·46	+1·44
7 664	7 700	24·75	31·67	6	3·2	08·15	−1·25
7 733	7 754	47·91	32·08	6	3·2	07·03	−0·13
7 778	7 807	22·83	33·57	5	3·0	06·65	+0·25
7 823	7 896	10·80	50·50	6	3·2	07·69	−0·79
7 945	[2 064]	59·29	11·88	6	3·2	06·61	+0·29
7 995	8 032	27·73	06·22	6	3·2	07·45	−0·55
8 071	8 124	42·71	42·57	6	3·2	07·74	−0·84
8 141	8 224	42·69	32·78	5·5	3·1	05·54	+1·36
8 250	8 273	04·79	35·78	5	3·0	07·70	−0·80
8 300	(4 057)	12·57	09·90	5	3·0	06·18	+0·72
28	58	38·36	48·84	5	3·0	07·12	−0·22
100	120	11·25	51·96	5	3·0	06·38	+0·52

Indiscriminate mean = 38° 21′ 06″·89.
Weighted mean = 38 21 06·90 ± 0″·12.
$e = \pm$ 0″·67.

115 observations, 21 pairs. Weighted mean of 3 series 38° 21′ 06″·87 ± 0″·10.
[Reduction to geodetic station 0″·00.]

* Practice observations were made at this station by W. B. Fairfield and D. S. Wolcott, aids. Their results were: Fairfield, 29″·00 ± 0″·12; Wolcott, 28″·57 ± 0″·15, mean = 28″·80. In view of the fact that these observers were then inexperienced this result has not been combined with that given above.

2. ALLEGHENY SERIES—completed.

(29) *Latitude at Piney, West Virginia.* A. T. Mosman. Meridian telescope No. 13. August 30 to September 9, 1883. One division of level = 2″·69. One turn of micrometer = 77″·793 from observations on Polaris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 748	6 810	00·23	11·76	6	14	38 26 41·28	+0·05
6 824	6 835	30·54	12·12	6	14	41·30	+0·03
6 852	6 868	02·44	08·89	6	14	40·93	+0·40
6 879	6 895	08·66	13·89	6	14	41·96	−0·63
6 928	6 979	47·18	19·74	6	14	40·78	+0·55
6 990	7 022	49·43	02·33	8	16	42·15	−0·82
7 098	7 107	56·58	43·48	7	15	41·06	+0·27
7 164	7 171	30·26	14·42	7	15	41·07	+0·26
7 246	7 278	25·88	13·28	6	14	41·30	+0·03
7 345	7 368	17·48	09·28	7	15	40·77	+0·56
7 462	7 521	28·66	42·22	7	15	41·72	−0·39
7 547	7 597	08·65	58·32	6	14	41·22	+0·11
7 676	7 706	53·66	33·66	5·5	14	41·50	−0·17
7 733	7 754	47·92	32·04	5·5	14	41·19	+0·14
7 778	7 807	22·83	33·57	6	14	41·03	+0·30
7 848	7 893	00·40	58·37	6	14	41·87	−0·54
7 943	7 967	36·90	53·57	6	14	41·51	−0·18
7 995	8 032	28·14	06·21	6	14	41·36	−0·03

Indiscriminate mean = 38° 26′ 41″·33.
Weighted mean = 38 26 41 ·33 ± 0″·06.
$e = \pm 0''·40$.
113 observations, 18 pairs.
[Reduction to geodetic station − 0″·44.]

3. OHIO SERIES.

(30) *Latitude at Gould, Ohio.* A. T. Mosman. Meridian telescope No. 7.* August 27 to September 11, 1885. One division of level = 1″·04 from observations at this station. One turn of micrometer = 78″·232 from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
(2 898)	6 235	56 ·37	12 ·54	6	1 ·1	38 38 30 ·94	−0 ·98
6 341	[1 586]	12 ·58	46 ·16	6	1 ·1	29 ·65	+0 ·31
6 429	6 475	13 ·04	17 ·98	6	1 ·1	30 ·43	−0 ·47
6 510	6 552	24 ·42	24 ·13	7	1 ·2	29 ·81	+0 ·15
6 581	6 599	05 ·08	14 ·49	7	1 ·2	31 ·05	−1 ·09
6 640	6 654	19 ·70	34 ·75	7	1 ·2	28 ·56	+1 ·40
6 690	(3 190)	52 ·86	22 ·05	6	1 ·1	28 ·93	+1 ·03
6 817	6 875	33 ·05	18 ·87	7	1 ·2	30 ·25	−0 ·29
6 928	6 979	26 ·47	58 ·01	6	1 ·1	30 ·87	−0 ·91
(3 383)	7 029	27 ·07	50 ·53	6	1 ·1	28 ·85	+1 ·11
7 098	7 107	32 ·56	19 ·28	6	1 ·1	28 ·94	+1 ·02
(3 475)	7 241	52 ·85	25 ·42	7	1 ·2	30 ·08	−0 ·12
7 256	7 294	45 ·61	04 ·23	6	1 ·1	33 ·97	−4 ·01
7 345	7 368	48 ·92	39 ·96	5	1 ·1	30 ·28	−0 ·32
7 417	7 418	46 ·44	13 ·64	7	1 ·2	27 ·93	+2 ·03
7 465	7 480	41 ·19	58 ·84	4	1 ·1	28 ·58	+1 ·38
7 627	7 676	56 ·31	19 ·66	2	0 ·9	30 ·43	−0 ·47

Indiscriminate mean = 38° 38′ 29″·97.
Weighted mean = 38 38 29 ·96 ± 0″·23.
$e = \pm$ 0″·85.
101 observations, 17 pairs.
[Reduction to geodetic station − 2″·00.]

*Instrument defective; object glass loose.

3. OHIO SERIES—continued.

(31) *Latitude at Minerva, Kentucky.* A. T. Mosman. Zenith telescope No. 6. August 3–13, 1887. One division of level = 0″·88 derived from the latitude observations at this station. One turn of micrometer = 76″·160 from observations on Polaris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 821	5 840	49 ·13	47 ·69	6	21	38 42 30 ·90	−0 ·02
5 847	5 874	22 ·73	51 ·34	6	21	30 ·26	+0 ·62
5 927	5 990	25 ·53	59 ·59	7	22	31 ·39	−0 ·51
6 068	6 082	13 ·23	02 ·55	6	21	31 ·38	−0 ·50
6 091	6 151	51 ·41	08 ·93	6	21	30 ·91	−0 ·03
(2 898)	6 235	54 ·96	09 ·72	6	21	30 ·55	+0 ·33
6 251	6 395	52 ·16	29 ·07	6	21	30 ·80	+0 ·08
6 478	6 471	59 ·16	44 ·65	6	21	31 ·12	−0 ·24
6 510	6 552	14 ·68	13 ·32	6	21	30 ·71	+0 ·17
6 583	6 589	59 ·31	31 ·03	6	21	31 ·20	−0 ·32
6 615	6 662	00 ·54	11 ·14	5	20	30 ·73	+0 ·15
6 690	6 734	38 ·19	24 ·99	6	21	31 ·02	−0 ·14
6 740	6 799	24 ·37	18 ·67	6	21	30 ·85	+0 ·03
6 824	6 883	54 ·65	40 ·90	6	21	31 ·10	−0 ·22
6 928	6 979	05 ·44	36 ·27	6	21	30 ·36	+0 ·52
(3 383)	7 029	04 ·23	27 ·64	5	20	30 ·74	+0 ·14

Indiscriminate mean = 38° 42′ 30″·88.
Weighted mean = 38 42 30 ·88 ± 0″·05.
$e = \pm 0''\cdot 29$.
95 observations, 16 pairs.
[Reduction to geodetic station = 0″·00.]

3. OHIO SERIES—continued.

(32) *Latitude at Cincinnati,* Ohio.* C. H. Sinclair. Transit No. 4. July 19–27, 1881. One division of level = 2″·123, from office determination of July, 1881. One turn of micrometer = 41″·400, from observations upon δ Ursæ Minoris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 922	5 937	55 ·36	36 ·16	6	8	39 08 18 ·98	+1 ·52
5 978	5 991	03 ·12	29 ·52	5	8	20 ·80	−0 ·30
5 999	(2 804)	30 ·16	52 ·58	4	7	20 ·00	+0 ·50
6 047	(2 822)	35 ·73	22 ·95	5	8	20 ·46	+0 ·04
6 079	6 106	29 ·87	10 ·23	5	8	20 ·78	−0 ·28
6 203	6 235	50 ·22	18 ·19	5	8	20 ·31	+0 ·19
6 268	*6 355	25 ·08	35 ·05	5	5	20 ·19	+0 ·31
*6 355	6 391	35 ·05	39 ·26	5	5	19 ·87	+0 ·63
6 404	6 466	06 ·94	06 ·51	5	8	20 ·85	−0 ·35
6 496	(3 071)	33 ·06	07 ·79	5	8	20 ·65	−0 ·15
6 520	6 534	59 ·68	56 ·45	5	8	20 ·77	−0 ·27
6 572	6 625	26 ·21	19 ·94	5	8	20 ·41	+0 ·09
6 667	6 718	12 ·06	50 ·53	5	8	20 ·42	+0 ·08
6 735	6 802	29 ·01	41 ·92	5	8	20 ·01	+0 ·49
6 817	6 849	08 ·96	44 ·02	5	8	20 ·74	−0 ·24
6 867	6 901	16 ·56	56 ·27	5	8	21 ·68	−1 ·18
6 968	(3 372)	15 ·10	27 ·68	5	8	20 ·30	+0 ·20
7 067	7 085	40 ·19	52 ·24	5	8	20 ·65	−0 ·15
7 098	7 146	20 ·46	44 ·14	5	8	21 ·10	−0 ·60
7 171	7 204	39 ·74	29 ·60	5	8	20 ·61	−0 ·11
(3 484)	7 246	51 ·15	52 ·28	5	8	20 ·49	+0 ·01

Indiscriminate mean = 39° 08′ 20″·48.
Weighted mean = 39 08 20 ·50 ± 0″·08.
$e = \pm$ 0″·43.
105 observations, 21 pairs.
[Reduction to center of dome — 0″·96; also to geodetic station — 1″·09.]

* Astronomic observatory on Mount Lookout.

3. OHIO SERIES—completed.

(33) *Latitude at Reizin, Indiana.* W. B. Fairfield. Meridian telescope No. 7. October 10–17, 1889. One division of level = 0″·90, from the latitude observations at this station. One turn of micrometer = 78″·400, from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
7 627	7 676	49 ·13	10 ·64	6	6	39 02 53 ·15	+0 ·43
7 733	7 749	02 ·89	45 ·01	6	6	53 ·31	+0 ·27
7 807	7 848	45 ·25	10 ·43	6	6	54 ·45	−0 ·87
7 874	7 868	43 ·61	22 ·15	6	6	53 ·67	−0 ·09
7 901	7 915	38 ·59	15 ·12	6	6	54 ·79	−1 ·21
7 932	[2 063]	47 ·77	01 ·62	6	6	54 ·26	−0 ·68
7 972	(3 843)	39 ·82	26 ·21	6	6	52 ·91	+0 ·67
8 031	8 074	39 ·48	45 ·33	6	6	53 ·64	−0 ·06
8 078	8 106	57 ·60	01 ·97	6	6	53 ·27	+0 ·31
8 195	8 212	24 ·93	32 ·22	6	6	54 ·10	−0 ·52
8 238	8 243	14 ·30	51 ·23	6	6	52 ·70	+0 ·88
(4 004)	(4 028)	26 ·04	34 ·57	6	6	53 ·59	−0 ·01
7	32	45 ·25	38 ·63	5	5	53 ·39	+0 ·19
51	(43)	10 ·27	57 ·18	5	5	52 ·66	+0 ·92
102	126	07 ·84	51 ·71	6	6	53 ·41	+0 ·17
166	198	47 ·65	24 ·11	6	6	53 ·31	+0 ·27
227	259	32 ·69	10 ·47	5	5	54 ·44	−0 ·86
285	330	31 ·19	01 ·20	5	5	53 ·24	+0 ·34

Indiscriminate mean = 39° 02′ 53″·57.
Weighted mean = 39 02 53 ·58 ± 0″·10.
$e = \pm 0''·47$.
104 observations, 18 pairs.
[Reduction to geodetic station + 0″·02.]

4. INDIANA SERIES.

(34) *Latitude at Weed Patch, Indiana.* J. B. Baylor. Meridian telescope No. 7. August 23–29, 1889. One division of level = 1″·05 as determined at office, June, 1889. One turn of micrometer = 78″·365 from observations upon circumpolars at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 082	(2 898)	04·03	53·33	5	13	39 09 60·59	−0·04
6 203	6 235	41·82	06·90	5	13	60·14	+0·41
6 355	6 391	09·48	11·62	6	18	60·41	+0·14
6 466	6 473	31·47	21·08	5	12	59·90	+0·65
6 582	6 640	41·47	53·14	5	11	60·55	0·00
6 667	6 718	16·03	49·45	5	13	61·36	−0·81
6 748	6 827	10·26	34·61	6	13	60·32	+0·23
6 849	6 857	29·51	49·10	5	13	60·93	−0·38
6 897	6 932	47·55	36·45	5	14	61·06	−0·51
6 990	*2 629	43·26	20·77	6	4	60·65	−0·10
7 067	7 085	05·75	17·06	5	14	60·98	−0·43
7 103	7 241	44·43	31·71	5	13	60·22	+0·33
7 275	(3 523)	11·23	07·12	5	13	60·30	+0·25
7 368	7 431	41·41	12·11	5	14	60·16	+0·39
7 542	7 567	07·64	32·18	5	14	60·62	−0·07
7 598	7 607	14·29	32·99	5	14	60·96	−0·41
7 681	7 753	07·50	33·02	5	13	60·44	+0·11
7 807	7 848	45·20	10·17	5	14	60·18	+0·37
7 901	7 915	38·59	14·99	5	13	60·76	−0·21
7 945	7 961	06·13	09·19	5	13	60·47	+0·08

Indiscriminate mean = 39° 10′ 00″·55.
Weighted mean = 39 10 00 ·55 ± 0″·06.
$e = \pm 0''\cdot55$.
103 observations, 20 pairs.
[Reduction to geodetic station 0″·00.]

*Number in Armagh Catalogue of 1875.

4. INDIANA SERIES—completed.

(35) *Latitude at Vincennes, Indiana.* C. H. Sinclair. Transit No. 4. October 19 to November 15, 1881. One division of level = 2″·12, determined at office July, 1881. One turn of micrometer = 41″·399 from observations upon Polaris. But the object glass was found to give a field which was not plane, as indicated by both the micrometer observations and the latitude observations. In reducing the latitude observations the value 41″·426 was used for all observations within 5′ 30″ of the middle of the field and the value 41″·293 for all other observations.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v.
		″	″			° ′ ″	″
(3 565)	7 503	32·17	02·01	6	10	38 40 37·22	−0·45
7 521	7 566	14·35	38·82	5	9	36·91	−0·14
7 627	7 676	03·53	28·24	6	10	36·64	+0·13
7 712	7 754	33·24	07·72	6	10	36·59	+0·18
7 798	7 855	06·74	44·52	5	9	36·31	+0·46
7 880	7 901	52·38	07·76	5	9	36·72	+0·05
[2 058]	7 958	50·04	35·40	6	7	36·78	−0·01
(3 843)	8 023	59·98	48·38	5	9	35·94	+0·83
8 052	8 107	25·42	40·90	6	10	37·01	−0·24
8 159	8 224	07·03	11·74	6	10	36·68	+0·09
8 273	8 300	15·75	52·62	5	9	36·68	+0·09
(4 052)	8 366	31·31	55·40	3	8	35·92	+0·85
28	67	17·92	26·54	6	10	37·35	−0·58
121	(88)	05·17	23·70	6	10	37·38	−0·61
166	197	25·70	18·14	6	10	36·16	+0·61
219	229P	52·72	15·72	4	9	36·61	+0·16
(4 025)	8 330	51·00	26·53	4	9	36·68	+0·09
16	(51)	24·61	56·65	4	9	36·83	−0·06
153	178	29·67	25·73	4	9	37·58	−0·81
250	314	59·90	50·93	4	9	36·78	−0·01
330	345	35·45	30·91	4	9	36·70	+0·07
431	456	36·05	45·93	5	9	37·32	−0·55
482	523	46·15	38·20	5	9	37·73	−0·96
558	593	33·11	06·51	5	9	36·78	−0·01
676	697	38·99	16·81	5	9	37·07	−0·30
710	731	26·43	03·10	4	9	36·24	+0·53
(371)	816	47·96	11·02	5	9	36·17	+0·60
827	861	33·61	53·62	5	9	36·81	−0·04
921	948	11·63	46·56	5	9	36·93	−0·16
(482)	999	15·53	51·35	5	9	37·30	−0·53
1 006	1 017	49·18	49·64	5	9	36·93	−0·16
1 025	1 059	04·01	13·54	3	8	35·61	+1·16

Indiscriminate mean = 38° 40′ 36″·76.
Weighted mean = 38 40 36 ·77 ± 0″·06.
$e = \pm 0''{\cdot}36$.
158 observations, 32 pairs.
[Reduction to geodetic station, Court-house − 0″·48.]

5. ILLINOIS SERIES.

Station No. 36. Parkersburg, Richland County, Illinois. "No. 24, Professional Papers of the Corps of Engineers of the United States Army." Report of the Primary Triangulation of the United States Lake Survey. Lieut. Col. C. B. Comstock, United States Army, Washington, 1882, pp. 633, 634. The latitude was observed here by Lieut. P. M. Price, on five nights in August, 1879, with United States Lake Survey Zenith telescope No. 19, having a focal length of 81 centimetres and an aperture of 7·6 centimetres. The number of pairs of stars observed was 38 and 126 individual results for latitude were obtained; $e = \pm 0''\cdot42$. Resulting latitude of observing post 38° 34′ 53″·25, and when reduced to trigonometric station 38° 34′ 53″·20 ± 0″·09.

Station No. 37. Olney West Base, Jasper County, Illinois. Reference as above, pp. 632, 633. The latitude was observed here by Assistant Engineer G. Y. Wisner, on four nights in May, 1880, with Zenith telescope No. 19, as above. The number of pairs observed was 30 and 115 individual results were obtained; $e = \pm 0''\cdot42$. Resulting latitude of observing post 38° 51′ 41″·23, and when referred to the trigonometric station 38° 51′ 41″·23 ± 0″·06.

(38) *Latitude at Newton, Illinois.* F. W. Perkins. Meridian telescope No. 13. October 16–29, 1883. One division of level = 2″·69, determined at office, August, 1879. One turn of micrometer = 77″·722 from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
7 399	7 402	38·39	46·06	5	9	38 55 31·15	−0·28
7 455	7 465	31·21	12·97	5	9	30·15	+0·72
7 521	7 566	42·16	06·27	5	9	31·41	−0·54
7 582	(3 652)	23·15	16·78	6	5	30·71	+0·16
7 627	7 676	29·82	53·66	5	9	30·78	+0·09
7 712	7 778	58·40	22·83	5	9	30·65	+0·22
7 800	7 843	09·16	33·27	6	10	30·88	−0·01
7 879	*7 901	37·94	30·45	2	4	30·38	+0·49
7 880	*7 901	15·60	30·45	6	7	30·87	0·00
7 932	[2 063]	40·72	54·91	6	8	31·20	−0·33
7 961	(3 865)	03·53	20·18	5	9	30·42	+0·45
8 039	8 149	17·18	38·51	5	9	30·67	+0·20
8 195	8 212	23·41	30·91	5	9	31·44	−0·57
(3 995)	*8 296	54·12	46·68	5	6	31·18	−0·31
*8 296	8 310	46·68	06·06	5	6	30·84	+0·03
(4 038)	(4 043)	25·84	54·63	5	8	31·76	−0·89
(4 052)	8 366	50·83	15·20	5	9	30·37	+0·50
8 373	26	18·94	01·00	4	9	30·24	+0·63
51	(43)	10·85	57·19	5	9	30·40	+0·47
102	126	07·10	51·28	5	9	30·89	−0·02
166	198	45·93	22·48	5	9	30·80	+0·07
285	330	27·41	56·44	5	9	31·92	−1·05

Indiscriminate mean = 38° 55′ 30″·87.
Weighted mean = 38 55 30 ·87 ± 0″·07.
$e = \pm 0''\cdot40$.
110 observations, 22 pairs.
[Reduction to geodetic station 0″·00.]

5. ILLINOIS SERIES—completed.

(39) *Latitude at Bording, Illinois.* G. A. Fairfield. Meridian telescope No. 7. October 10–20, 1882. One division of level = 1″·005 determined at this station. One turn of micrometer = 78″·298 from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 640	6 654	39·42	54·68	5	9	38 36 50·09	+0·64
6 740	6 799	04·73	01·70	5	14	50·32	+0·41
6 879	6 895	18·28	23·85	5	14	50·71	+0·02
6 928	6 979	57·70	30·50	5	14	50·65	+0·08
7 200	7 220	01·03	09·58	5	14	50·08	+0·65
7 246	7 278	38·90	27·00	5	13	50·81	−0·08
7 345	7 368	31·70	23·66	5	14	50·99	−0·26
7 474	7 555	40·03	51·14	5	14	50·73	0·00
7 595	7 606	24·63	45·18	5	14	50·37	+0·36
7 676	7 706	10·91	51·13	5	14	50·82	−0·09
7 731	(3 719)	01·35	39·35	5	6	50·93	−0·20
7 798	7 855	48·55	26·04	5	14	50·54	+0·19
7 879	*7 901	56·47	49·10	3	7	50·20	+0·53
7 880	*7 901	34·13	49·10	5	9	50·76	−0·03
[2 058]	7 958	31·30	16·47	5	3	50·50	+0·23
8 052	8 107	05·94	21·51	5	14	50·63	+0·10
8 273	8 300	55·78	32·57	5	14	50·85	−0·12
(4 057)	14	29·90	39·12	5	4	50·51	+0·22
166	197	05·88	57·47	5	13	51·80	−1·07
219	229_M	33·03	57·06	5	14	51·14	−0·41
247	254	06·67	24·80	5	14	51·19	−0·46

Indiscriminate mean = 38° 36′ 50″·70.
Weighted mean = 38 36 50·73 ± 0″·06.
$e = \pm 0''{\cdot}42$.
103 observations, 21 pairs.
[Reduction to geodetic station 0″·00.]

6. MISSOURI SERIES.

(40) *Latitude at St. Louis, Missouri.* O. H. Tittmann and W. Eimbeck. Zenith telescope No. 6. December 8–27, 1869, and July 3 to November 7, 1870. One division of level = 1″·12, determined at Salt Lake City, Utah, in 1869. One turn of micrometer = 76″·160 from observations upon circumpolars at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
146	178	13 ·20	22 ·87	1	1 ·3	38 38 00 ·14	+2 ·63
219	229	48 ·46	12 ·00	2	1 ·7	03 ·97	−1 ·20
330	345	27 ·04	21 ·69	3	1 ·9	02 ·74	+0 ·03
502	544	15 ·14	02 ·42	4	2 ·1	04 ·02	−1 ·25
676	697	04 ·14	36 ·77	4	2 ·1	03 ·68	−0 ·91
827	861	39 ·77	55 ·63	4	2 ·1	02 ·65	+0 ·12
1 219	1 269	17 ·32	21 ·37	3	1 ·9	02 ·22	+0 ·55
1 530	1 535	39 ·38	48 ·48	2	1 ·7	00 ·84	+1 ·93
1 631	1 663	14 ·64	24 ·59	3	1 ·9	03 ·18	−0 ·41
5 084	5 155	56 ·45	25 ·01	1	1 ·3	04 ·83	−2 ·06
5 315	5 348	14 ·40	12 ·70	2	1 ·7	04 ·04	−1 ·27
5 367	5 459	17 ·90	45 ·22	1	1 ·3	01 ·39	+1 ·38
5 502	5 525	54 ·16	31 ·60	1	1 ·3	02 ·31	+0 ·46
5 546	5 617	22 ·49	44 ·79	1	1 ·3	01 ·55	+1 ·22
5 667	5 731	20 ·79	50 ·19	2	1 ·7	02 ·74	+0 ·03
5 823	5 841	30 ·53	33 ·22	1	1 ·3	03 ·10	−0 ·33
5 834	5 874	34 ·76	46 ·69	2	1 ·7	02 ·25	+0 ·52
*5 937	5 988	05 ·06	14 ·74	3	1 ·3	03 ·04	−0 ·27
*5 937	5 999	05 ·06	07 ·16	3	1 ·3	01 ·50	+1 ·27
6 062	*6 082	17 ·46	50 ·89	3	1 ·3	02 ·46	+0 ·31
6 068	*6 082	58 ·62	50 ·89	1	0 ·9	02 ·47	+0 ·30
6 129	6 150	27 ·17	13 ·43	4	2 ·1	02 ·57	+0 ·20
6 185	6 241	05 ·26	44 ·41	3	1 ·9	03 ·10	−0 ·33
6 348	6 387	11 ·50	34 ·80	3	1 ·9	01 ·99	+0 ·78
6 429	6 475	12 ·35	26 ·27	2	1 ·7	02 ·64	+0 ·13
6 623	6 674	13 ·79	47 ·88	1	1 ·3	02 ·44	+0 ·33
6 644	6 662	54 ·30	08 ·10	1	1 ·3	03 ·06	−0 ·29
6 690	6 734	42 ·56	43 ·97	2	1 ·7	04 ·68	−1 ·91
6 858	6 867	33 ·66	01 ·47	1	1 ·3	03 ·30	−0 ·53
6 937	7 027	30 ·68	18 ·83	1	1 ·3	03 ·57	−0 ·80
7 567	7 595	42 ·87	42 ·67	1	1 ·3	01 ·93	+0 ·84
7 612	7 627	33 ·67	08 ·18	1	1 ·3	04 ·49	−1 ·72
7 820	7 914	56 ·06	12 ·96	1	1 ·3	01 ·15	+1 ·62
8 052	8 107	58 ·49	13 ·69	1	1 ·3	02 ·85	−0 ·08
8 147	8 188	12 ·06	03 ·06	1	1 ·3	01 ·51	+1 ·26
8 248	8 279	09 ·30	28 ·79	1	1 ·3	00 ·56	+2 ·21
98	126	41 ·37	10 ·00	1	1 ·3	01 ·74	+1 ·03
235	256	11 ·71	45 ·56	1	1 ·3	04 ·90	−2 ·13
285	330	40 ·04	07 ·69	1	1 ·3	05 ·06	−2 ·29

Indiscriminate mean = 38° 38′ 02″·73.
Weighted mean = 38 38 02 ·77 ± 0″·13.
$e = \pm 0''·65$.

74 observations, 39 pairs. The first nine pairs were observed in 1869 and the remainder in 1870.

[Reduction to spire of Second Presbyterian Church — 1″·97.]

6. MISSOURI SERIES—continned.

Latitude at St. Louis, Missouri. F. H. Parsons. Transit No. 6. September 24 to October 10, 1881. One division of level = 2″·12, determined at office in July, 1881. One turn of micrometer = 44″·168, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
7 568	7 598	39 ·98	26 ·45	5	5	38 38 03 ·43	−0 ·62
7 686	7 689	11 ·40	21 ·07	5	5	02 ·31	+0 ·50
7 723	7 758	13 ·62	41 ·71	5	5	02 ·44	+0 ·37
7 798	7 855	06 ·50	44 ·62	5	5	02 ·40	+0 ·41
7 880	7 901	52 ·38	07 ·72	5	5	03 ·22	−0 ·41
[2 058]	7 958	49 ·78	35 ·20	5	5	02 ·24	+0 ·57
(3 843)	8 023	59 ·79	48 ·29	5	5	01 ·81	+1 ·00
8 074	8 105	21 ·20	03 ·75	5	5	02 ·22	+0 ·59
8 136	8 212	01 ·25	10 ·37	5	5	03 ·39	−0 ·58
8 273	8 300	15 ·91	53 ·41	5	5	02 ·64	+0 ·17
(4 025)	8 330	50 ·68	26 ·53	4	4	02 ·75	+0 ·06
8 344	(4 052)	23 ·73	31 ·60	4	4	02 ·80	+0 ·01
121	(88)	05 ·05	23 ·71	4	4	02 ·72	+0 ·09
166	197	26 ·07	16 ·00	5	5	02 ·58	+0 ·23
219	229	52 ·56	15 ·10	4	4	03 ·20	−0 ·39
247	254	25 ·70	43 ·44	5	5	04 ·05	−1 ·24
330	345	34 ·82	30 ·91	5	5	03 ·02	−0 ·21
427	456	51 ·44	45 ·81	5	5	02 ·08	+0 ·73
487	514	31 ·03	19 ·01	4	4	04 ·42	−1 ·61

Indiscriminate mean = 38° 38′ 02″·83.
Weighted mean = 38 38 02 ·81 ± 0″·09.
$e = \pm 0''\cdot 76$.
90 observations, 19 pairs.
[Reduction to spire of Second Presbyterian Church — 2″·40.]

6. MISSOURI SERIES—completed.

(41) *Latitude at Jefferson, Missouri.* H. W. Blair. Meridian telescope No. 3. November 19–29, 1879. One division of level = 1″·82, a mean of several determinations. One turn of micrometer = 63″·800, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
7 902	(3 805)	39·84	10·87	4	10	38 33 43·97	+0·02
[2 058]	7 958	27·06	13·22	5	11	43·02	+0·97
7 973	7 975	47·07	01·74	5	11	44·01	-0·02
8 052	[2 097]	03·92	16·80	5	11	43·45	+0·54
*8 195	*8 195	42·45	42·45	5	6	43·88	-0·11
(4 057)	14	30·20	39·42	5	11	43·67	+0·32
101	148	38·72	25·66	5	11	43·86	+0·13
166	197	05·55	56·44	5	11	44·75	−0·76
219	229	31·86	54·45	5	11	44·18	−0·19
247	254	05·74	22·63	5	11	44·36	−0·37
264	314	09·84	26·58	5	11	44·57	−0·58
330	345	13·49	09·37	5	11	44·47	−0·48
427	*456	29·20	23·08	5	7	44·02	−0·03
431	*456	13·63	23·08	5	7	44·50	−0·51
482	523	22·90	12·95	5	11	44·08	−0·09
566	579	06·18	58·90	4	10	43·25	+0·74
593	614	41·31	54·15	5	11	43·52	+0·47
676	697	13·20	50·05	5	11	44·23	−0·24
745	744	17·95	34·97	5	11	43·70	+0·29
777	794	46·00	08·06	5	11	44·30	−0·31

Indiscriminate mean = 38° 33′ 43″·99.
Weighted mean = 38 33 43·99 ± 0″·07.
$e = \pm 0''{\cdot}37$.
98 observations, 20 pairs.
[Reduction to geodetic station 0″·00.]

7. MISSOURI-KANSAS SERIES.

(42) *Latitude at Hunter, Missouri.* F. D. Granger. Meridian telescope No. 3. July 26 to August 3, 1880. One division of level = 1″·78, determined at Jefferson City, in 1879, by H. W. Blair. One turn of micrometer = 63″·422, from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 860	5 937	48·96	33·56	6	4·4	38 25 47·22	+0·79
5 962	5 990	23·80	45·50	5	4·2	48·74	−0·73
6 052	6 073	23·94	47·58	5	4·2	47·26	+0·75
6 109	6 178	32·74	24·59	5	4·2	48·37	−0·36
6 218	6 235	37·41	19·20	5	4·2	47·27	+0·74
6 251	6 395	01·33	54·52	5	4·2	49·14	−1·13
6 429	6 475	32·96	41·68	5	4·2	48·23	−0·22
6 522	6 574	48·01	47·86	5	4·2	48·49	−0·48
6 601	*6 654	06·20	08·07	5	2·8	48·67	−0·66
6 640	*6 654	54·72	08·07	5	2·8	48·20	−0·19
6 698	6 745	05·09	29·60	5	4·2	48·59	−0·58
6 824	6 835	57·32	39·28	5	4·2	48·44	−0·43
6 857	6 875	14·10	07·13	6	4·4	48·50	−0·49
6 928	6 979	22·17	52·08	5	4·2	46·59	+1·42
7 098	7 107	32·47	19·96	5	4·2	47·02	+0·99
7 149	*7 220	37·42	37·10	5	2·8	48·58	−0·57
7 200	*7 220	26·40	37·10	6	2·9	48·64	−0·63
7 246	7 278	05·90	54·11	5	4·2	47·62	+0·39
7 345	7 368	59·73	52·46	5	4·2	48·46	−0·45
7 465	7 503	59·65	16·95	6	4·4	47·29	+0·72
7 568	7 598	56·80	42·91	6	4·4	47·03	+0·98
*7 705	7 721	08·97	47·95	5	2·8	48·83	−0·82
*7 705	7 731	08·97	36·54	5	2·8	47·95	+0·06

Indiscriminate mean = 38° 25′ 48″·05.
Weighted mean = 38 25 48·01 ± 0″·10.
$e = \pm 0''·62$.
120 observations, 23 pairs.
[Reduction to geodetic station 0″·00.]

7. MISSOURI-KANSAS SERIES—continued.

(43) *Latitude at Kansas City, Missouri.* C. H. Sinclair. Transit No. 4. September 20–26, 1882. One division of level = 2″·12, determined at office, July, 1881. One turn of micrometer = 41″·333, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 520	6 534	54 ·71	51 ·23	4	7	39 05 51 ·29	−0 ·37
6 574	6 583	36 ·75	29 ·18	4	7	50 ·68	+0 ·24
6 667	6 718	05 ·00	42 ·79	5	7	50 ·98	−0 ·06
6 794	6 852	09 ·90	12 ·36	6	7	50 ·93	−0 ·01
6 867	6 901	07 ·01	47 ·38	5	7	51 ·26	−0 ·34
6 928	6 966	58 ·01	04 ·10	4	7	50 ·13	+0 ·79
6 986	7 061	58 ·20	47 ·77	4	7	51 ·69	−0 ·77
7 112	7 164	38 ·66	42 ·00	1	4	51 ·44	−0 ·52
7 211	7 223	17 ·78	44 ·63	1	4	50 ·28	+0 ·64
(3 484)	7 246	37 ·92	39 ·00	1	4	50 ·27	+0 ·65
7 275	(3 523)	46 ·87	46 ·08	1	4	51 ·18	−0 ·26
(3 565)	7 455	17 ·28	46 ·48	1	4	51 ·84	−0 ·92
7 542	7 567	59 ·95	26 ·52	2	6	51 ·30	−0 ·38
7 598	7 607	09 ·92	28 ·94	1	4	51 ·63	−0 ·71
7 945	7 961	18 ·14	22 ·10	5	7	51 ·12	−0 ·20
(3 841)	8 023	07 ·30	29 ·03	5	7	50 ·51	+0 ·41
8 078	8 106	13 ·33	19 ·82	5	7	52 ·05	−1 ·13
8 188	(3 957)	04 ·86	37 ·70	5	7	50 ·47	+0 ·45
8 238	8 243	34 ·38	09 ·78	4	7	50 ·10	+0 ·82
8 279	(4 052)	28 ·36	11 ·54	4	7	50 ·61	+0 ·31
8 366	8	35 ·34	38 ·11	4	7	50 ·04	+0 ·88

Indiscriminate mean = 39° 05′ 50″·94.
Weighted mean = 39 05 50 ·92 ± 0″·09.
$e = \pm 0''·33$.
72 observations, 21 pairs.
[Reduction to geodetic station, Second Presbyterian Church + 5″·41.]

7. MISSOURI-KANSAS SERIES—continued.

(44) *Latitude at Adams, Kansas.* F. H. Parsons. Meridian telescope No. 7. July 7–19, 1888. One division of level = 1″·06, derived from the latitude observations at this station. One turn of micrometer = 78″·356, from observations on Polaris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
4 980	5 031	57·80	10·81	6	5	39 02 41·43	+0·29
5 071	(2 386)	16·61	28·96	6	5	41·65	+0·07
5 143	5 181	28·84	39·67	6	5	42·16	−0·44
(2 455)	5 315	16·41	17·99	6	5	41·63	+0·09
5 348	5 426	07·63	31·57	6	5	41·48	+0·24
5 511	5 520	12·98	13·12	6	5	41·54	+0·18
5 574	5 597	28·78	29·13	6	5	42·44	−0·72
5 628	5 647	54·84	32·63	6	5	42·50	−0·78
(2 658)	(2 690)	09·79	14·88	6	5	41·62	+0·10
5 860	(2 732)	18·65	21·95	6	5	41·75	−0·03
5 918	(2 761)	15·55	42·07	6	5	41·48	+0·24
5 978	5 991	22·46	42·92	8	6	42·27	−0·55
(2 793)	6 073	39·54	54·09	8	6	41·79	−0·07
6 114	6 101	22·80	29·09	8	6	41·21	+0·51
6 203	6 235	42·86	08·81	7	5	41·82	−0·10
6 297	(2 976)	19·42	57·01	8	6	41·24	+0·48
6 355	6 390*P*	12·68	48·54	5	5	43·47	−1·75
6 469	6 460	40·07	29·41	7	5	41·71	+0·01
6 496	(3 071)	00·55	34·55	6	5	40·89	+0·83
6 520	6 534	24·99	21·76	6	5	40·41	+1·31

Indiscriminate mean = 39° 02′ 41″·72.
Weighted mean = 39 02 41 ·72 ± 0″·10.
$e = \pm 0''\cdot 65$.
129 observations, 20 pairs.
[Reduction to geodetic station − 0″·06.]

7. MISSOURI-KANSAS SERIES—completed.

(45) *Latitude at Salina West Base, Kansas.* W. C. Hodgkins. Meridian telescope No. 2. July 30 to August 10, 1896. One division of level = 1″·663, determined at office November, 1890. One turn of micrometer = 65″·572, from observations on Polaris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 527	5 643	36·36	56·27	1	0·2	38 51 03·72	−0·15
5 740	5 765	22·98	58·67	4	0·8	03·44	+0·13
5 821	5 840	28·04	25·58	3	0·6	04·19	−0·62
5 871	5 927	26·27	51·53	7	1·4	04·46	−0·89
5 978	5 991	44·71	58·10	6	1·2	06·02	−2·45
6 073	*6 091	00·37	56·31	7	0·7	04·71	−1·14
*6 091	6 151	56·31	06·33	2	0·2	04·34	−0·77
*6 091	6 152	56·31	51·44	2	0·2	02·38	+1·19
(2 883)	(2 898)	33·91	48·14	2	0·4	01·34	+2·23
6 238	6 255	45·94	52·31	6	1·2	02·41	+1·16
6 300	[1 586]	10·40	06·48	4	0·8	04·24	−0·67
6 520	6 571	45·78	24·51	5	1·0	03·78	−0·21
6 583	6 582	04·94	58·84	4	0·8	02·28	+1·29
6 615	6 662	02·73	08·91	6	1·2	03·27	+0·30
*6 690	(3 190)	31·67	58·89	6	0·6	02·10	+1·47
*6 690	6 734	31·67	11·25	7	0·7	02·92	+0·65
*6 690	6 730	31·67	40·95	1	0·1	03·18	+0·39
6 754	(3 233)	19·99	11·32	2	0·4	01·18	+2·39
6 783	6 852	20·08	59·05	7	1·4	04·68	−1·11
6 890	6 970	38·10	11·84	6	1·2	03·02	+0·55
6 990	7 022	25·94	34·47	5	1·0	01·84	+1·73
[1 819]	7 126	41·11	00·46	1	0·2	05·59	−2·02
7 164	7 233	45·82	18·44	2	0·4	04·14	−0·57
7 256	7 278	16·73	15·19	2	0·4	04·06	−0·49

Indiscriminate mean = 38° 51′ 03″·47.
Weighted mean = 38 51 03 ·57 ± 0″·18.
$e = \pm 2''·22$.
98 observations, 24 pairs.
[Reduction to geodetic station 0″·00.]

8. KANSAS-COLORADO SERIES.

(46) *Latitude at Ellsworth, Kansas.* E. Smith. Transit No. 4. September 17–25, 1885. One division of level = 2″·1, determined at the office in 1881. One turn of micrometer = 41″·395, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
7 256	7 294	45 ·61	04 ·23	4	3 ·1	38 43 48 ·51	−0 ·91
7 320	7 398	48 ·66	13 ·42	4	3 ·1	47 ·74	−0 ·14
7 417	7 418	46 ·51	13 ·28	4	3 ·1	46 ·16	+1 ·44
7 474	7 555	53 ·25	02 ·16	4	3 ·1	48 ·83	−1 ·23
7 595	7 606	35 ·00	55 ·40	4	3 ·1	46 ·46	+1 ·14
7 627	7 676	56 ·29	19 ·48	4	3 ·1	48 ·28	−0 ·68
7 731	(3 719)	08 ·96	46 ·30	3	2 ·9	47 ·23	+0 ·37
7 798	7 855	54 ·68	30 ·96	4	3 ·1	48 ·48	−0 ·88
7 880	*7 901	38 ·61	53 ·20	4	2 ·1	48 ·04	−0 ·44
[2 058]	7 958	33 ·76	19 ·73	4	3 ·1	46 ·82	+0 ·78
(3 843)	8 023	42 ·92	31 ·20	4	3 ·1	47 ·24	+0 ·36
8 052	8 107	08 ·40	23 ·96	4	3 ·1	48 ·99	−1 ·39
8 153	8 227	49 ·32	11 ·78	4	3 ·1	46 ·34	+1 ·26
7 268	(3 530)	21 ·66	34 ·67	3	2 ·9	47 ·22	+0 ·38
(3 555)	7 437	07 ·50	10 ·50	3	2 ·9	46 ·62	+0 ·98
7 521	7 566	10 ·28	33 ·54	3	2 ·9	47 ·56	+0 ·04
7 585	7 631	51 ·95	37 ·02	3	2 ·9	48 ·41	−0 ·81
7 686	7 689	02 ·90	11 ·28	4	3 ·1	47 ·39	+0 ·21
7 712	7 754	23 ·62	56 ·38	5	3 ·3	48 ·08	−0 ·48
(3 754)	*7 901	33 ·29	53 ·20	4	2 ·1	47 ·61	−0·01

Indiscriminate mean = 38° 43′ 47″·60.
Weighted mean = 38 43 47 ·60 ± 0″·13.
$e = \pm 0''\cdot53$.
76 observations, 20 pairs.
[Reduction to geodetic station 0″·00.]

8. KANSAS-COLORADO SERIES—continued.

(47) *Latitude at Russell Southeast Base, Kansas.* H. L. Stidham. Meridian telescope No. 1. September 21–30, 1893. One division of level = 1″·901, determined at office April, 1893. One turn of micrometer = 65″·987, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 656	6 698	14 ·28	28 ·13	6	16	38 51 23 ·16	−0 ·26
6 740	6 799	35 ·60	26 ·96	6	15	22 ·31	+0 ·59
6 890	6 932	07 ·84	55 ·00	6	18	22 ·23	+0 ·67
6 957	7 062	45 ·78	17 ·76	5	16	22 ·88	+0 ·02
[1 819]	7 126	17 ·55	37 ·54	5	14	23 ·01	−0 ·11
7 256	7 278	57 ·37	56 ·40	6	19	23 ·50	−0 ·60
7 333	7 399	56 ·79	08 ·71	5	17	22 ·80	+0 ·10
7 465	7 480	36 ·17	52 ·69	5	14	22 ·46	+0 ·44
7 627	7 676	41 ·85	01 ·38	6	18	23 ·34	−0 ·44
7 712	7 754	04 ·36	33 ·79	5	12	22 ·76	+0 ·14
7 800	7 843	09 ·09	30 ·20	6	16	23 ·14	−0 ·24
7 880	7 901	10 ·36	23 ·95	6	16	23 ·16	−0 ·26
7 923	7 999	18 ·37	15 ·87	6	19	22 ·90	0 ·00
8 052	8 107	33 ·44	49 ·17	5	17	22 ·69	+0 ·21
8 159	8 224	10 ·26	17 ·93	5	14	23 ·08	−0 ·18
8 296	8 310	26 ·79	45 ·78	5	14	22 ·83	+0 ·07

Indiscriminate mean = 38° 51′ 22″·89.
Weighted mean = 38 51 22 ·90 ± 0″·06.
$e = \pm 0''\cdot48$.
88 observations, 16 pairs.
[Reduction to geodetic station 0″·00.]

8. KANSAS-COLORADO SERIES—continued.

(48) *Latitude at Wallace, Kansas.* E. Smith. Transit No. 4. October 8–14, 1885. One division of level = 2″·1, determined at office July, 1881. One turn of micrometer = 41″·366, from latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 615	6 662	13 ·28	24 ·82	4	4	38 54 44 ·62	−0 ·24
6 690	6 734	52 ·61	41 ·46	4	4	44 ·86	−0 ·48
6 783	6 852	55 ·68	42 ·80	4	4	45 ·19	−0 ·81
6 926	(3 331)	15 ·85	31 ·19	4	4	44 ·23	+0 ·15
(3 338)	6 976	58 ·16	01 ·93	5	5	44 ·27	+0 ·11
6 986	6 990	25 ·84	27 ·38	3	4	43 ·31	+1 ·07
7 022	7 061	39 ·62	12 ·90	5	5	45 ·01	−0 ·63
7 098	7 146	32 ·39	54 ·86	6	5	43 ·56	+0 ·82
7 164	7 233	04 ·86	43 ·95	5	5	43 ·75	+0 ·63
7 961	(3 865)	25 ·30	40 ·57	5	5	44 ·34	+0 ·04
8 031	8 074	56 ·62	03 ·10	5	5	43 ·88	+0 ·50
8 159	8 224	48 ·16	53 ·73	5	5	43 ·98	+0 ·40
8 296	8 310	06 ·71	25 ·91	5	5	46 ·03	−1 ·65
(4 038)	(4 043)	47 ·48	14 ·02	5	5	44 ·04	+0 ·34
(4 052)	8 366	11 ·06	35 ·10	4	4	44 ·79	−0 ·41
7	32	04 ·66	58 ·83	5	5	44 ·34	+0 ·04

Indiscriminate mean = 38° 54′ 44″·39.
Weighted mean = 38 54 44 ·38 ± 0″·12.
$e = \pm 0''·66$.
74 observations, 16 pairs.
[Reduction to geodetic station 0″·00.]

8. KANSAS-COLORADO SERIES—continued.

(49) *Latitude at Adobe, Colorado.* O. H. Tittmann. Zenith telescope No. 4. July 28 to August 4, 1881. One division of level $= 0''.896$; from observations at this station. One turn of micrometer $= 44''.712$, from observations on Polaris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		$''$	$''$			° ′ ″	$''$
5 667	5 731	31 ·95	51 ·12	4	9	38 40 37 ·67	−0 ·14
5 821	5 840	22 ·86	22 ·36	5	10	38 ·20	−0 ·67
5 874	5 886$_x$	28 ·80	36 ·70	5	10	36 ·87	+0 ·66
5 927	5 990	08 ·60	47 ·25	5	10	37 ·56	−0 ·03
6 062	*6 082	28 ·44	58 ·62	4	6	37 ·68	−0 ·15
6 068	*6 082	08 ·12	58 ·62	4	6	37 ·74	−0 ·21
(2 898)	6 235	57 ·33	08 ·07	4	9	37 ·18	+0 ·35
*6 355	*6 355	34 ·79	34 ·79	5	7	37 ·28	+0 ·25
6 397	6 463	59 ·91	24 ·61	4	9	37 ·95	−0 ·42
6 542	6 551	58 ·18	08 ·44	4	9	38 ·04	−0 ·51
6 623	6 674	02 ·44	30 ·34	4	9	36 ·98	+0 ·55
6 754	(3 233)	24 ·41	16 ·41	4	9	36 ·44	+1 ·09
6 779	(3 258)	32 ·92	09 ·04	4	9	37 ·65	−0 ·12
(3 267)	(3 294)	44 ·24	18 ·30	3	8	38 ·30	−0 ·77
6 879	6 895	28 ·49	33 ·41	4	9	38 ·03	−0 ·50
6 928	6 979	08 ·25	41 ·41	4	9	37 ·37	+0 ·16
6 990	7 022	11 ·11	24 ·85	4	9	37 ·31	+0 ·22
7 098	7 173	20 ·46	05 ·43	4	9	37 ·68	−0 ·15
(3 475)	7 241	44 ·76	18 ·48	4	9	37 ·83	−0 ·30
7 256	7 294	39 ·88	59 ·34	3	8	36 ·97	+0 ·56

Indiscriminate mean $= 38° \; 40' \; 37''.54$.
Weighted mean $= 38 \; 40 \; 37 \; .53 \pm 0''.07$.
$e = \pm 0''.46$.
82 observations, 20 pairs.
[Reduction to geodetic station $+ 0''.01$.]

8. KANSAS-COLORADO SERIES—continued.

(50) *Latitude at El Paso East Base, Colorado.* O. H. Tittmann. Meridian telescope No. 3. September 25 to October 3, 1879. One division of level = 1″·866, from observations at this station. One turn of micrometer = 63″·793, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 574	6 583	53 ·68	47 ·37	4	6	38 57 16 ·58	+0 ·32
6 690	(3 190)	36 ·75	07 ·46	5	7	16 ·41	+0 ·49
6 731	6 784	18 ·95	10 ·53	5	7	17 ·42	−0 ·52
6 867	6 901	36 ·75	16 ·49	5	7	17 ·00	−0 ·10
7 022	7 061	47 ·37	23 ·09	5	7	17 ·12	−0 ·22
[1 819]	7 126	07 ·39	28 ·77	5	7	15 ·98	+0 ·92
(3 475)	7 253	11 ·40	12 ·85	5	7	16 ·88	+0 ·02
7 275	(3 523)	27 ·59	28 ·41	5	7	16 ·77	+0 ·13
7 399	7 402	37 ·17	45 ·61	5	7	16 ·74	+0 ·16
7 455	7 465	33 ·13	15 ·20	5	7	16 ·30	+0 ·60
7 505	7 521	28 ·30	45 ·87	5	7	17 ·78	−0 ·88
7 733	7 749	58 ·08	41 ·72	5	7	17 ·04	−0 ·14
7 800	7 843	20 ·44	45 ·55	5	7	17 ·95	−1 ·05
7 901	7 915	45 ·08	22 ·50	5	7	17 ·26	−0 ·36
7 945	7 961	14 ·59	20 ·37	4	6	16 ·08	+0 ·82

Indiscriminate mean = 38° 57′ 16″·89.
Weighted mean = 38 57 16 ·90 ± 0″·10.
$e = \pm 0''·45$.
73 observations, 15 pairs.
[Reduction to geodetic station + 0″·15.]

9. ROCKY MOUNTAIN SERIES.

(51) *Latitude at Colorado Springs, Colorado.* E. Smith. Meridian telescope No. 13. August 30 to September 11, 1873. One division of level = 2″·53, determined at office in August, 1871. One turn of micrometer = 77″·774, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 397	6 463	29 ·30	59 ·50	5	5	38 49 59 ·46	+0 ·88
6 487	6 508	09 ·53	28 ·45	5	5	59 ·87	+0 ·47
6 520	6 571	38 ·40	37 ·58	5	5	60 ·86	−0 ·52
6 583	6 589	23 ·20	55 ·40	6	5	60 ·43	−0 ·09
6 623	6 657	55 ·14	52 ·88	5	5	60 ·67	−0 ·33
6 690	6 734	19 ·70	20 ·52	6	5	59 ·64	+0 ·70
6 758	6 824	50 ·62	00 ·47	3	5	60 ·26	+0 ·08
6 862	6 868	19 ·01	44 ·60	3	5	59 ·80	+0 ·54
6 890	6 932	25 ·50	22 ·47	5	5	59 ·36	+0 ·98
6 943	6 959	04 ·83	04 ·37	5	5	61 ·29	−0 ·95
6 990	7 022	39 ·28	55 ·04	5	5	61 ·28	−0 ·94
7 098	7 149	56 ·24	04 ·33	6	5	60 ·80	−0 ·46
7 204	7 253	15 ·75	33 ·54	4	5	59 ·99	+0 ·35
7 333	7 399	40 ·20	06 ·50	5	5	61 ·09	−0 ·75

Indiscriminate mean = 38° 50′ 00″·34.
Weighted mean = 38 50 00 ·34 ± 0″·12.
$e = \pm 0''·40$.
68 observations, 14 pairs.
[Reduction to geodetic station 0″·00.]

9. ROCKY MOUNTAIN SERIES—continued.

(52) *Latitude at Pikes Peak, Colorado.* R. L. Faris. Zenith telescope No. 6. July 19 to August 4, 1895. One division of level = 2″·17, determined at office January, 1893. One turn of micrometer = 76″·204, from observations on Polaris at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 348	5 426	15 ·48	36 ·69	1	3	38 50 26 ·82	+1 ·07
5 460	5 496	25 ·54	00 ·60	1	3	27 ·43	+0 ·46
5 545	5 621	17 ·04	32 ·62	2	5	27 ·92	−0 ·03
5 667	5 731	02 ·00	08 ·28	2	5	27 ·94	−0 ·05
5 821	5 840	23 ·72	21 ·43	3	6	28 ·11	−0 ·22
5 871	5 927	22 ·59	48 ·66	4	7	28 ·54	−0 ·65
5 978	5 991	41 ·93	56 ·22	5	8	27 ·79	+0 ·10
6 073	6 091	59 ·60	55 ·76	6	9	28 ·22	−0 ·33
6 109	(2 874)	38 ·46	43 ·30	5	8	27 ·07	+0 ·82
(2 888)	(2 898)	17 ·55	48 ·88	3	6	29 ·01	−1 ·12
6 246	(2 950)	54 ·40	48 ·38	6	9	28 ·29	-0 ·40
6 348	6 387	05 ·54	15 ·28	7	9	28 ·75	−0 ·86
6 469	6 460	10 ·00	58 ·33	7	9	27 ·90	−0 ·01
6 520	6 571	50 ·74	30 ·34	7	9	27 ·73	+0 ·16
6 583	6 589	10 ·99	41 ·79	7	9	27 ·33	+0 ·56
6 656	6 698	00 ·57	13 ·13	4	7	27 ·54	+0 ·35
6 731	6 784	15 ·74	59 ·98	6	9	27 ·42	+0 ·47
6 890	6 970	48 ·02	22 ·66	5	8	28 ·58	−0 ·69
6 990	7 022	37 ·00	45 ·86	4	7	27 ·56	+0 ·33
[1 819]	7 126	53 ·26	12 ·82	3	6	27 ·02	+0 ·87

Indiscriminate mean = 38° 50′ 27″·85.
Weighted mean = 38 50 27 ·89 ± 0″·09.
$e = \pm 0''{\cdot}55$.
88 observations, 20 pairs.
[Reduction to geodetic station 0″·00.]

9. ROCKY MOUNTAIN SERIES—continued.

(53) *Latitude at Mount Ouray, Colorado.* R. L. Faris. Meridian telescope No. 3. July 7–23, 1894. One division of level = 1″·186, determined at office April, 1894. One turn of micrometer = 65″·078, from circumpolar observations at the station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
4 936	4 951	40 ·75	32 ·59	1	4	38 25 17 ·50	+1 ·15
5 098	5 177	43 ·73	10 ·87	1	4	19 ·42	—0 ·77
5 248	5 252	55 ·04	12 ·18	2	5	18 ·54	+0 ·11
5 287	5 319	09 ·42	35 ·77	2	5	20 ·38	—1 ·73
5 479	5 552	04 ·21	39 ·50	3	6	19 ·06	—0 ·41
5 667	5 731	55 ·59	02 ·78	2	5	18 ·70	—0 ·05
5 823	5 841	17 ·37	13 ·66	4	6	18 ·81	—0 ·16
5 860	5 937	41 ·41	12 ·56	4	6	19 ·40	—0 ·75
5 975	6 021	09 ·79	02 ·15	6	7	18 ·19	+0 ·46
6 052	6 073	38 ·09	58 ·82	6	7	18 ·36	+0 ·29
6 134	6 185	26 ·72	42 ·16	6	7	18 ·90	—0 ·25
6 245	6 289	35 ·56	38 ·81	6	7	18 ·64	+0 ·01
6 395	6 438	04 ·34	09 ·02	5	7	18 ·83	—0 ·18
6 476	6 547	23 ·87	16 ·81	4	6	17 ·78	+0 ·87
6 595	6 662	44 ·27	22 ·72	6	7	18 ·46	+0 ·19
6 701	6 735	45 ·28	09 ·11	5	7	18 ·09	+0 ·56
6 748	6 810	28 ·51	33 ·23	2	5	19 ·03	—0 ·38
6 856	6 883	33 ·16	31 ·84	3	6	18 ·00	+0 ·65
6 932	6 952	44 ·63	30 ·68	4	6	18 ·46	+0 ·19
7 098	7 107	44 ·17	28 ·97	4	6	18 ·34	+0 ·31
7 146	7 220	02 ·70	22 ·64	4	6	19 ·05	—0 ·40
7 246	7 278	59 ·65	42 ·66	4	6	18 ·80	—0 ·15

Indiscriminate mean = 38° 25′ 18″·67.
Weighted mean = 38 25 18 ·65 ± 0″·08.
$e = \pm 0''\cdot 40$.
84 observations, 22 pairs.
[Reduction to geodetic station — 0″·66.]

9. ROCKY MOUNTAIN SERIES—continued.

(54) *Latitude at Treasury Mountain, Colorado.* John Nelson. Meridian telescope No. 3. September 4–10, 1893. One division of level = 1″·94. One turn of micrometer = 63″·872, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 238	6 255	50 ·49	57 ·37	4	7	39 00 48 ·61	−0 ·60
6 348	6 438	10 ·87	13 ·15	4	7	47 ·50	+0 ·51
6 453	6 522	24 ·78	41 ·82	4	7	48 ·72	−0 ·71
6 574	6 583	32 ·62	23 ·08	4	7	48 ·14	−0 ·13
6 623	6 674	44 ·38	05 ·69	5	7	47 ·78	+0 ·23
6 690	(3 190)	53 ·78	21 ·65	6	7	47 ·96	+0 ·05
6 722	6 769	33 ·98	01 ·64	5	7	47 ·23	+0 ·78
6 928	6 966	02 ·08	04 ·70	6	7	48 ·69	−0 ·68
6 990	7 027	59 ·09	58 ·54	6	7	47 ·32	+0 ·69
[1 819]	7 126	16 ·49	37 ·54	5	7	48 ·36	−0 ·35
7 194	(3 480)	15 ·09	44 ·85	6	7	48 ·62	−0 ·61
7 256	7 278	57 ·37	56 ·40	5	7	47 ·99	+0 ·02
7 333	7 399	56 ·80	08 ·71	5	7	46 ·95	+1 ·06
7 455	7 465	56 ·48	36 ·17	5	7	48 ·02	−0 ·01
†3 597	7 568	22 ·25	26 ·79	3	2	46 ·96	+1 ·05
7 585	7 631	40 ·30	22 ·49	5	7	48 ·21	−0 ·20
7 733	7 749	52 ·59	34 ·41	5	7	47 ·73	+0 ·28
7 807	7 848	32 ·86	57 ·07	5	7	48 ·08	−0 ·07
7 932	[2 063]	32 ·45	46 ·10	5	7	48 ·38	−0 ·37

Indiscriminate mean = 39° 00′ 47″·96.
Weighted mean = 39 00 48 ·01 ± 0″·08.
$e = \pm 0''\cdot 38$.
93 observations, 19 pairs.
[Reduction to geodetic station + 0″·85.]

† Bonn, Durchmusterung 49°.

9. ROCKY MOUNTAIN SERIES—continued.

(55) *Latitude at Gunnison, Colorado.* J. Nelson. Meridian telescope No. 3. October 9–11, 1893. One division of level = 1″·94. One turn of micrometer = 63″·894, from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 879	6 895	30 ·89	35 ·09	3	7	38 32 45 ·01	−0 ·15
6 928	6 979	02 ·08	30 ·64	3	7	45 ·08	−0 ·22
(3 383)	7 029	55 ·68	18 ·90	3	7	45 ·02	−0 ·16
7 188	[1 861]	43 ·95	59 ·58	3	7	45 ·40	−0 ·54
7 246	7 278	12 ·94	56 ·40	3	7	44 ·24	+0 ·62
7 345	7 368	54 ·14	42 ·94	3	7	44 ·67	+0 ·19
7 401	(3 591)	05 ·57	17 ·36	3	7	45 ·19	−0 ·33
7 555	7 585	51 ·96	40 ·30	3	7	45 ·32	−0 ·46
7 598	7 623	08 ·09	26 ·97	3	7	44 ·20	+0 ·66
7 676	7 706	01 ·38	39 ·14	3	7	44 ·62	+0 ·24
7 733	7 778	52 ·59	24 ·22	2	7	44 ·63	+0 ·23
7 798	7 855	30 ·54	03 ·64	3	7	45 ·21	−0 ·35
(3 807)	7 958	42 ·53	48 ·32	3	7	45 ·13	−0 ·27
(3 854)	8 052	10 ·90	33 ·44	3	7	45 ·66	−0 ·80
8 141	8 224	26 ·22	17 ·93	3	7	43 ·56	+1 ·30

Indiscriminate mean = 38° 32′ 44″·86.
Weighted mean = 38 32 44 ·86 ± 0″·10.
$e = \pm 0''{\cdot}21$.
44 observations, 15 pairs.
[Reduction to geodetic station − 0″·45.]

9. ROCKY MOUNTAIN SERIES—continued.

(56) *Latitude at Uncompahgre, Colorado.* J. Nelson and R. L. Faris. Meridian telescope No. 3. September 5-11, 1895. One division of level = 1''·186, determined at office April, 1894. One turn of micrometer = 65''·052, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		"	"			° ' "	"
6 030	6 079	40·05	39·25	4	9	38 04 15·40	+0·99
6 109	6 147	38·46	11·46	4	9	16·63	−0·24
6 185	6 231	41·19	59·42	5	10	17·16	−0·77
6 300	6 350	12·61	47·70	5	10	16·63	−0·24
6 427	6 475	11·93	31·85	5	10	16·65	−0·26
(3 068)	6 543	00·10	25·52	5	10	15·81	+0·58
6 602	6 623	49·11	31·33	5	10	15·77	+0·62
6 637	(3 190)	20·72	06·48	5	10	16·34	+0·05
6 794	6 847	16·24	06·65	5	10	16·39	0·00
6 895	6 943	15·29	14·76	5	10	16·97	−0·58
6 975	(3 372)	24·34	52·89	4	9	16·39	0·00
7 067	7 112	54·70	00·36	5	10	16·83	−0·44
7 158	7 213	31·17	42·39	5	10	16·90	−0·51
7 262	7 275	07·97	48·73	6	11	15·88	+0·51
7 368	7 455	13·70	25·49	5	10	16·31	+0·08
7 522	7 564	07·45	56·08	5	10	15·84	+0·55
7 631	‡5 047	48·85	19·80	4	9	16·65	−0·26
†4 671	7 746	14·38	43·57	6	11	16·40	−0·01

Indiscriminate mean = 38° 04' 16''·39.
Weighted mean = 38 04 16 ·39 ± 0''·08.
$e = \pm 0''·48$.
88 observations, 18 pairs.
[Reduction to geodetic station + 0''·29.]

‡ Bonn, Durchmusterung 20°. † Bonn, Durchmusterung 25°.

9. ROCKY MOUNTAIN SERIES—continued.

(57) *Latitude at Grand Junction, Colorado.* C. H. Sinclair. Transit No. 4. July 18–27, 1886. One division of level = 2″·123, determined at office July, 1881. One turn of micrometer = 41″·334, from latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 122	*5 178	40·64	36·97	1	3	39 03 59·74	−0·35
5 130	*5 178	48·13	36·97	4	7	59·87	−0·48
5 234	(2 455)	20·91	54·12	2	7	59·24	+0·15
5 313	5 322	40·12	42·67	5	12	60·13	−0·74
5 348	5 426	48·23	12·80	6	13	59·42	−0·03
5 918	(2 761)	09·39	36·39	4	11	60·37	−0·98
5 978	5 991	16·88	39·08	2	7	59·78	−0·39
6 079	6 106	33·73	12·50	2	7	59·59	−0·20
6 203	6 235	44·99	11·13	2	7	59·19	+0·20
6 268	6 355	16·22	19·00	4	11	59·39	0·00
6 395	6 453	32·67	55·23	4	11	59·11	+0·28
6 520	6 534	35·37	32·32	4	11	59·21	+0·18
6 574	6 583	13·45	05·36	2	7	58·57	+0·82
6 582	6 640	59·55	13·28	2	7	59·15	+0·24
6 667	6 718	37·07	12·70	4	11	58·94	+0·45
6 758	6 824	01·33	03·64	3	9	59·75	−0·36
6 849	6 857	57·65	17·63	4	11	58·55	+0·84
6 897	6 970	16·24	59·54	2	7	59·58	−0·19
6 968	(3 372)	20·94	33·37	2	7	58·69	+0·70
7 022	7 061	28·26	01·22	3	9	59·69	−0·30
[1 819]	7 126	40·98	03·97	3	9	59·93	−0·54
7 140	7 215	54·65	45·29	3	9	58·73	+0·66

Indiscriminate mean = 39° 03′ 59″·39.
Weighted mean = 39 03 59 ·39 ± 0″·07.
$e = \pm 0''\cdot 43$.
68 observations, 22 pairs.
[Reduction to geodetic station 0″·00.]

9. ROCKY MOUNTAIN SERIES—continued.

(58) *Latitude at Tavaputs, Colorado.* P. A. Welker. Meridian telescope No. 3. October 4–9, 1891. One division of level = 1''·94. One turn of micrometer = 63·863, from latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		''	''			° ' ''	''
6 623	6 637	57 ·43	47 ·55	6	31	39 32 17 ·35	0 ·00
6 690	6 697	08 ·51	08 ·61	6	31	17 ·77	−0 ·42
6 718	6 722	34 ·00	49 ·64	5	28	17 ·53	−0 ·18
*6 868	6 932	52 ·33	15 ·73	6	18	17 ·30	+0 ·05
*6 868	6 970	52 ·33	05 ·91	6	19	17 ·03	+0 ·32
6 979	(3 372)	52 ·44	37 ·57	6	28	17 ·32	+0 ·03
7 037	7 065	06 ·26	07 ·95	6	22	17 ·36	−0 ·01
(3 437)	7 174	02 ·61	23 ·75	5	18	17 ·51	−0 ·16
7 204	7 233	16 ·38	24 ·61	6	30	17 ·32	+0 ·03
*7 277	7 320	08 ·56	24 ·12	6	13	17 ·97	−0 ·62
*7 277	7 336	08 ·56	11 ·30	6	21	17 ·71	−0 ·36
7 401	7 437	35 ·63	38 ·67	6	22	17 ·16	+0 ·19
7 453	7 544	12 ·14	15 ·49	6	25	17 ·23	+0 ·12
7 560	7 568	28 ·17	59 ·05	6	25	17 ·17	+0 ·18
7 590	*7 699	34 ·56	38 ·10	6	13	17 ·62	−0 ·27
7 606	*7 699	15 ·92	38 ·10	6	20	16 ·93	+0 ·42
7 733	7 755	27 ·74	23 ·22	6	23	17 ·50	−0 ·15
7 798	7 815	06 ·59	01 ·44	6	31	17 ·83	−0 ·48
7 855	7 923	40 ·48	55 ·84	6	31	17 ·14	+0 ·21
7 958	7 961	26 ·18	31 ·13	6	31	17 ·25	+0 ·10
7 997	8 054	56 ·06	09 ·57	6	28	17 ·33	+0 ·02
8 125	8 141	21 ·70	05 ·56	6	23	17 ·14	+0 ·21
8 177	[2 145]	11 ·35	04 ·85	6	2	17 ·34	+0 ·01
8 268	8 296	18 ·96	06 ·77	6	18	17 ·21	+0 ·14
8 359	8	09 ·60	38 ·41	6	23	17 ·52	−0 ·17
(34)	58	37 ·07	09 ·04	6	30	16 ·86	+0 ·49

Indiscriminate mean = 39° 32′ 17''·36.
Weighted mean = 39 32 17 ·35 ± 0''·03.
$e = \pm 0''\cdot32$.
154 observations, 26 pairs.
[Reduction to geodetic station − 0''·62.]

9. ROCKY MOUNTAIN SERIES—continued.

(59) *Latitude at Mount Waas, Utah.* John Nelson. Meridian telescope No. 3. July 17–27, 1893. One division of level = 1″·94. One turn of micrometer = 63″·887, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 287	5 319	58·98	24·89	4	3	38 32 28·24	+1·46
5 341	5 399	12·33	42·25	5	3	31·34	−1·64
5 502	5 525	05·65	37·56	4	3	30·55	−0·85
5 552	5 619	31·91	49·74	3	3	31·64	−1·94
5 667	5 731	49·16	57·20	4	3	30·04	−0·34
5 823	5 841	12·95	09·53	5	3	29·91	−0·21
5 874	5 886*	13·79	19·03	5	3	29·38	+0·32
5 911	5 931	00·54	53·12	4	3	28·73	+0·97
5 962	5 990	55·97	12·04	6	3	29·08	+0·62
6 052	6 073	37·12	58·03	6	3	29·32	+0·38
(2 858)	6 162	18·80	06·07	3	3	28·90	+0·80
(2 898)	6 235	50·28	01·22	5	3	29·81	−0·11
6 348	6 387	10·87	21·73	3	3	30·17	−0·47
6 429	6 475	41·19	41·04	6	3	30·10	−0·40
6 522	6 574	41·75	32·54	6	3	29·30	+0·40
6 640	6 654	26·27	40·11	4	3	29·36	+0·34
6 701	6 735	52·70	15·19	4	3	29·24	+0·46
6 748	6 810	36·90	42·21	5	3	30·53	−0·83
6 857	6 875	11·00	01·10	6	3	28·76	+0·94
6 928	6 979	02·09	30·64	5	3	29·85	−0·15
(3 383)	7 029	55·68	18·90	5	3	29·22	+0·48
(3 415)	[1 819]	23·85	18·63	4	3	29·91	−0·21

Indiscriminate mean = 38° 32′ 29″·70.
Weighted mean = 38 32 29·70 ± 0″·12.
$e = \pm 0''{\cdot}45$.
102 observations, 22 pairs.
[Reduction to geodetic station + 0″·88.]

9. ROCKY MOUNTAIN SERIES—continued.

(60) *Latitude at Green River, Utah.* C. H. Sinclair. Zenith telescope No. 6. July 28–31, 1898. One division of level = 2″·172, determined at office January, 1893. One turn of micrometer = 76″·227, from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 574	*5 597	42·32	40·55	3	9	38 59 23·33	+0·56
5 575	*5 597	15·09	40·55	3	8	23·51	+0·38
5 667	5 693	21·26	46·27	4	16	24·16	−0·27
5 714	*(2 690)	23·54	00·24	4	11	23·83	+0·06
(2 658)	*(2 690)	02·62	00·24	4	10	23·58	+0·31
(2 709)	(2 721)	22·80	16·41	4	13	23·66	+0·23
5 860	(2 732)	56·51	57·04	4	9	24·77	−0·88
5 940	5 972	39·88	00·24	4	16	23·92	−0·03
5 978	5 991	50·27	01·87	4	16	24·29	−0·40
6 005	(2 804)	40·39	19·76	4	12	24·20	−0·31
*6 079	6 110	41·20	00·07	4	11	24·04	−0·15
*6 079	6 157	41·20	06·03	4	11	23·79	+0·10
*6 246	(2 949)	49·96	57·74	4	11	23·89	0·00
*6 246	(2 950)	49·96	42·57	4	11	24·01	−0·12
6 355	(2 996)	40·80	08·63	3	14	23·42	+0·47
[1 586]	(3 021)	56·86	34·64	4	8	23·48	+0·41

Indiscriminate mean = 38° 59′ 23″·87.
Weighted mean = 38 59 23 ·89 ± 0″·06.
$e = \pm 0''\cdot33$.
61 observations, 16 pairs.
[Reduction to geodetic station 0″·00.]

9. ROCKY MOUNTAIN SERIES—continued.

(61) *Latitude at Patmos Head, Utah.* P. A. Welker. Meridian telescope No. 3. September 22 to October 20, 1890. One division of level = 1″·94, a mean of several determinations. One turn of micrometer = 63″·888, from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 589	6 640	12 ·53	46 ·43	7	13	39 29 57 ·29	−0 ·14
6 656	6 667	34 ·39	09 ·30	4	12	56 ·32	+0 ·83
6 690	6 697	15 ·87	16 ·15	7	13	57 ·40	−0 ·25
6 714	6 734	43 ·92	00 ·49	6	13	57 ·01	+0 ·14
6 754	6 784	10 ·02	41 ·04	6	13	56 ·37	+0 ·78
6 852	6 901	55 ·66	25 ·94	6	13	57 ·60	−0 ·45
6 928	6 940	33 ·68	18 ·15	6	13	57 ·00	+0 ·15
6 979	(3 372)	03 ·34	48 ·73	6	13	56 ·83	+0 ·32
7 027	7 061	32 ·61	14 ·45	6	13	56 ·48	+0 ·67
7 067	7 091	53 ·91	03 ·39	6	13	57 ·49	−0 ·34
(3 437)	7 174	14 ·98	36 ·51	6	13	57 ·13	+0 ·02
7 204	7 233	29 ·71	37 ·84	6	13	57 ·23	−0 ·08
*7 277	7 320	22 ·29	38 ·22	5	8	56 ·63	+0 ·52
*7 277	7 336	22 ·29	28 ·86	6	9	56 ·56	+0 ·59
7 368	7 411	26 ·80	18 ·43	6	13	56 ·84	+0 ·31
7 495	7 520	31 ·99	33 ·90	6	13	57 ·63	−0 ·48
*7 560	7 568	44 ·49	15 ·17	5	8	57 ·28	−0 ·13
*7 560	7 623	44 ·49	17 ·11	5	8	57 ·10	+0 ·05
7 659	7 686	35 ·17	37 ·44	5	12	57 ·28	−0 ·13
7 733	7 755	45 ·31	40 ·90	5	12	57 ·32	−0 ·17
*7 814	7 857	50 ·55	29 ·62	5	8	57 ·54	−0 ·39
*7 814	7 874	50 ·55	25 ·05	5	8	57 ·62	−0 ·47
(3 799)	7 945	32 ·74	47 ·27	5	12	57 ·53	−0 ·38
7 997	8 054	15 ·29	28 ·97	5	12	57 ·75	−0 ·60
8 125	8 141	41 ·40	25 ·22	5	12	57 ·04	+0 ·11
8 211	8 224	40 ·28	16 ·36	6	13	57 ·55	−0 ·40

Indiscriminate mean = 39° 29′ 57″·14.
Weighted mean = 39 29 57 ·15 ± 0″·06.
$e = \pm 0''\cdot 32$.
146 observations, 26 pairs.
[Reduction to geodetic station − 1″·81.]

9. ROCKY MOUNTAIN SERIES—continued.

(62) *Latitude at Mount Ellen, Utah.* P. A. Welker. Meridian telescope No. 3. August 17-24, 1891. One division of level = 1″·94. One turn of micrometer = 63″·800, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 740	5 802	55·28	56·82	7	10	38 07 24·53	+0·13
(2 717)	5 886M	36·21	12·10	7	10	25·02	−0·36
5 917	5 991	36·02	48·64	6	10	24·42	+0·24
6 033	6 052	26·10	35·14	6	10	24·57	+0·09
6 089	6 122	28·93	04·96	5	10	24·88	−0·22
6 134	6 185	27·06	45·09	5	10	25·33	−0·67
6 213	6 243	03·41	01·25	5	10	23·96	+0·70
6 245	6 289	40·34	44·82	5	10	25·23	−0·57
6 300	6 350	21·39	58·68	5	10	24·65	+0·01
[1 586]	6 453	24·10	33·50	5	3	23·64	+1·02
6 475	6 491	50·22	35·06	5	10	24·81	−0·15
6 583	6 654	35·17	53·79	4	10	24·47	+0·19
6 698	6 718	43·04	34·00	5	10	24·64	+0·02
6 745	6 784	01·05	32·81	5	10	24·12	+0·54
6 835	6 856	58·15	01·48	5	10	24·42	+0·24
6 912	6 928	58·30	23·15	5	10	24·76	−0·10
6 975	(3 372)	07·79	37·57	5	10	24·41	+0·25
7 067	7 112	42·05	49·23	5	10	24·70	−0·04
7 158	7 213	21·45	34·83	4	10	24·00	+0·66
7 320	7 336	24·12	11·33	5	10	25·23	−0·57
7 385	7 398	11·22	43·80	5	10	25·59	−0·93
7 437	7 468	38·67	29·87	5	10	24·43	+0·23

Indiscriminate mean = 38° 07′ 24″·63.
Weighted mean = 38 07 24 ·66 ± 0″·06.
$e = \pm 0''·26$.
114 observations, 22 pairs.
[Reduction to geodetic station +0″·48.]

9. ROCKY MOUNTAIN SERIES—continued.

(63) *Latitude at Wasatch, Utah.* P. A. Welker. Meridian telescope No. 3. August 5–19, 1890. One division of level = 1″·94, a mean of several determinations. One turn of micrometer = 63″·788, from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 856	5 917	44·69	32·81	7	12	39 06 55·40	−1·08
5 922	5 937	21·95	01·40	7	12	54·07	+0·25
5 978	5 991	28·02	46·74	6	12	54·85	−0·53
6 021	6 052	52·91	34·15	7	12	54·24	+0·08
6 079	6 106p	35·95	13·58	7	12	53·59	+0·73
6 203	6 235	40·76	05·48	7	12	54·38	−0·06
6 251	6 348	47·88	18·86	8	13	54·16	+0·16
6 404	6 466	35·38	27·07	7	12	54·57	−0·25
6 520	6 534	15·56	11·36	8	13	53·93	+0·39
6 574	6 583	50·14	41·21	6	12	54·07	+0·25
6 589	6 640	12·53	46·43	7	12	54·70	−0·38
6 667	6 718	08·99	41·73	7	12	54·31	+0·01
6 779	6 784	15·37	41·04	7	12	54·36	−0·04
6 802	6 836	18·55	44·34	8	13	54·57	−0·25
6 849	6 857	20·12	39·59	6	12	54·01	+0·31
6 897	6 932	37·98	26·09	7	12	54·94	−0·62
6 962	*7 029	01·41	53·30	7	8	54·28	+0·04
6 965	*7 029	31·77	53·30	7	8	54·32	0·00
7 061	*7 158	14·45	34·01	5	7	54·02	+0·30
(3 437)	*7 158	14·98	34·01	6	8	53·57	+0·75
7 171	7 204	45·30	29·71	7	12	54·56	−0·24
[1 861]	7 246	38·70	52·85	3	7	54·09	+0·23
7 275	(3 523)	57·49	53·00	3	9	53·83	+0·49

Indiscriminate mean = 39° 06′ 54″·29.
Weighted mean = 39 06 54 ·32 ± 0″·06.
$e = \pm 0''·37$.
150 observations, 23 pairs.
[Reduction to geodetic station − 3″·06.]

9. ROCKY MOUNTAIN SERIES—continued.

(64) *Latitude at Mount Nebo, Utah.* J. H. Turner. Meridian telescope No. 3. July 25 to August 1, 1887. One division of level = 3″·6, determined at this station. One turn of micrometer = 63″·90, from latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 388	5 432*N*	06 ·58	17 ·82	5	3	39 48 33 ·52	−0 ·62
5 459	5 466	15 ·08	51 ·50	8	3	32 ·23	+0 ·67
5 496	5 523	53 ·59	08 ·97	6	3	33 ·00	−0 ·10
5 740	5 749	33 ·22	40 ·58	7	3	32 ·54	+0 ·36
5 842	5 871	39 ·73	53 ·06	8	3	34 ·17	−1 ·27
5 911	5 927	41 ·50	25 ·55	7	3	33 ·46	−0 ·56
5 951	5 967	59 ·61	20 ·30	8	3	33 ·20	−0 ·30
6 052	6 150	31 ·18	09 ·26	7	3	32 ·39	+0 ·51
6 193	6 218	27 ·58	27 ·39	7	3	33 ·77	−0 ·87
6 387	6 463	41 ·00	58 ·74	7	3	33 ·33	−0 ·43
6 476	6 571	54 ·41	16 ·91	7	3	31 ·33	+0 ·47
6 612	6 615	14 ·13	00 ·49	5	3	32 ·58	+0 ·32
6 656	6 722	55 ·35	20 ·91	7	3	32 ·23	+0 ·67
6 745	6 771	33 ·72	05 ·44	6	3	32 ·72	+0 ·18
6 856	6 879	39 ·20	29 ·57	5	3	34 ·16	−1 ·26
6 912	6 976	39 ·02	40 ·12	7	3	34 ·13	−1 ·23
7 033	7 125	52 ·27	59 ·22	7	3	31 ·71	+1 ·19
7 213	7 241	27 ·22	58 ·52	6	3	33 ·63	−0 ·73
7 294*P*	7 368	36 ·96	10 ·63	7	3	31 ·04	+1 ·86
7 402	7 453	45 ·82	13 ·76	7	3	32 ·25	+0 ·65
7 495	7 528	19 ·39	39 ·24	6	3	32 ·90	0 ·00
7 555	7 571	29 ·62	26 ·87	7	3	33 ·46	−0 ·56

Indiscriminate mean = 39° 48′ 32″·90.
Weighted mean = 39 48 32 ·90 ± 0″·12.
$e = \pm 0''\!\cdot\!91$.
147 observations, 22 pairs.
[Reduction to geodetic station + 0″·59.]

Station No. 65. Gunnison, Utah. United States Geographical Surveys West of the One hundredth Meridian. Lieut. G. M. Wheeler, United States Engineers, in charge. Washington, 1877. Vol. II, pp. 99–125. Observations for latitude were made on 8 nights in November, 1872, by W. W. Marryatt, using the meridian instrument Würdemann No. 16. Focal length 26 inches, clear aperture 1¾ inches. Number of individual results for latitude 179. Resulting value for latitude 39° 09′ 25″·62 ± 0″·05.

[Reduction to geodetic station 0″·00.]

9. ROCKY MOUNTAIN SERIES—continued.

(66) *Latitude at Ogden Peak, Utah.* J. H. Turner. Meridian telescope No. 3. September 23–29, 1888. One division of level = 2″·35, determined at the office, July, 1888. One turn of micrometer = 63″·90, from latitude observations at Mount Nebo, 1887.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″ ″	″
6 623	6 648	16·98	50·52	7	9	41 11 59·50	+0·10
6 754	6 771	26·68	56·91	7	9	58·65	+0·95
6 830	6 851	25·44	50·08	7	9	59·26	+0·34
6 983	6 998	46·79	01·09	7	9	58·77	+0·83
7 194	[1 861]	20·02	04·77	7	9	59·91	−0·31
7 290	7 320	50·34	06·41	2	6	60·88	−1·28
7 398	7 402	28·62	30·80	6	9	59·26	+0·34
7 462	7 480	11·05	11·45	6	9	59·63	−0·03
7 521	7 544	22·18	04·15	6	9	59·63	−0·03
7 585	7 605	02·60	37·25	6	9	59·74	−0·14
7 706	7 749	06·42	02·72	6	9	59·29	+0·31
7 850	7 915	02·41	33·96	6	9	59·78	−0·18
7 972	7 984	58·48	12·19	4	8	59·08	+0·52
8 153	8 160	50·20	44·83	6	9	60·08	−0·48
8 212	8 229	52·09	07·31	6	9	59·93	−0·33
8 268	8 324	19·08	52·34	6	9	59·10	+0·50
(43)	79	17·59	03·27	6	9	59·68	−0·08
109	153	57·38	10·73	6	9	59·98	−0·38
178	244	06·95	02·06	6	9	60·09	−0·49
267	314	48·63	46·26	6	9	59·44	+0·16
343	404	19·14	30·72	6	9	59·76	−0·16
510	566	55·70	23·99	6	9	60·18	−0·58

Indiscriminate mean = 41° 11′ 59″·62.
Weighted mean = 41 11 59·60 ± 0″·07.
e = ± 0″·40.
131 observations, 22 pairs.
[Reduction to geodetic station − 0″·02.]

9. ROCKY MOUNTAIN SERIES—continued.

(67) *Latitude at Salt Lake City, Utah.* F. H. Agnew. Zenith telescope No. 6. March 23 to April 29, 1869. One division of level = 1″·12. One turn of micrometer = 76″·126, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
2 379	2 464	19·50	28·50	5	10	40 46 03·17	+0·61
2 441	2 485	55·30	37·70	6	11	03·69	+0·09
2 516	2 544	13·00	39·08	4	10	04·20	−0·42
2 576	2 617	51·48	51·50	6	11	03·43	+0·35
2 632	2 648	20·78	08·20	5	10	03·92	−0·14
2 700	2 704	34·72	16·57	7	11	03·74	+0·04
2 714	2 751	24·50	50·50	7	11	04·06	−0·28
2 786	2 792	37·40	39·80	7	11	04·46	−0·68
*2 819	2 917	49·96	55·30	5	7	02·96	+0·82
*2 819	2 918	46·96	05·50	5	7	03·99	−0·21
2 999	3 048	12·94	46·84	7	11	03·43	+0·35
3 059	3 097	02·45	35·00	6	11	03·80	−0·02
3 140	3 204	22·77	20·10	7	11	03·30	+0·48
3 242	3 255	39·17	09·27	7	11	04·53	−0·75
3 313	3 330	34·20	43·75	6	11	03·66	+0·12
3 358	3 371	30·84	38·99	6	11	03·30	+0·48
3 468	3 505	13·06	57·60	6	11	04·14	−0·36
3 533	3 584	33·50	19·05	6	11	04·41	−0·63
3 612	*3 671	39·05	35·57	7	7	03·54	+0·24
3 664	*3 671	50·25	35·57	7	7	03·64	+0·14
3 725	3 751	10·13	02·60	6	11	03·88	−0·10
3 787	3 825	22·80	39·55	5	10	04·09	−0·31
3 838	3 864	17·45	12·60	6	11	02·96	+0·82
3 904	3 915	33·12	08·76	7	11	03·93	−0·15
2 765	2 799	30·10	57·50	6	11	03·67	+0·11
2 817	2 887	21·90	42·12	6	11	04·11	−0·33
2 982	2 991	00·90	52·45	5	10	04·56	−0·78
3 068	3 085	16·04	04·08	6	11	03·84	−0·06
3 112	3 150	12·50	18·86	6	11	04·37	−0·59
3 178	3 218	20·25	34·75	6	11	03·11	+0·67
3 246	3 324	21·95	20·75	6	7	02·80	+0·98
3 331	3 402	26·56	46·00	7	11	03·93	−0·15
3 496	3 534	23·45	54·15	7	11	03·21	+0·57
3 665	3 728	31·00	46·50	7	11	04·14	−0·36
3 744	3 784	23·00	14·50	6	11	03·88	−0·10
3 811	3 868	48·81	58·20	6	11	03·92	−0·14
4 123	4 141	22·93	14·53	6	11	03·20	+0·58
4 188	4 235	16·32	48·40	6	11	03·75	+0·03
4 258	4 285	15·38	31·75	6	11	04·04	−0·26
4 300	4 351	12·50	00·90	6	11	04·13	−0·35

Indiscriminate mean = 40° 46′ 03″.77.
Weighted mean = 40 46 03 ·78 ± 0″·05.
$e = \pm 0''·35$.
244 observations, 40 pairs.
[Reduction to geodetic station 0″·00.]

9. ROCKY MOUNTAIN SERIES—continued.

Station No. 68. Ogden, United States Engineers' Observatory, Utah. From United States Geographical Surveys West of the One hundredth Meridian, Lieut. G. M. Wheeler, United States Engineers, in charge. Washington, 1877. Vol. II, pp. 7–54 and 469–471. Observations for latitude were made in 1873 and 1874 with the Würdemann combined transit instrument No. 28. In 1873 Dr. F. Kampf observed for latitude on 5 nights in October, number of pairs 36, and 140 individual results; resulting latitude 41° 13′ 08″·65 ± 0″·022. In 1874 Dr. John H. Clark observed for latitude on 7 nights in September and October, number of pairs 23, and 117 individual results; resulting latitude, 41° 13′ 08″·47. Mean of two results 41° 13′ 08″·56 ± 0″·03. The reference is to the longitude pier of the observatory.

[Reduction to geodetic station 0″·00.]

(69) *Latitude at Waddoup, Utah.* O. B. French. Meridian telescope No. 3. June 7–19, 1892. One division of level = 1″·94. One turn of micrometer = 63″·753, from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
(2 000)	4 335	02 ·79	14 ·41	2	4	40 54 22 ·55	−0 ·44
(2 036)	4 407	45 ·00	05 ·43	2	4	20 ·54	+1 ·57
4 433	4 438	30 ·69	28 ·19	2	4	22 ·07	+0 ·04
4 451	4 467	31 ·61	56 ·45	2	4	23 ·16	−1 ·05
4 540	4 594	52 ·99	21 ·25	3	4	21 ·93	+0 ·18
4 615	4 646	58 ·46	35 ·45	4	5	21 ·96	+0 ·15
4 664	[1 185]	36 ·36	02 ·30	4	5	22 ·03	+0 ·08
4 742	4 823	04 ·48	08 ·09	1	2	21 ·36	+0 ·75
4 845	4 864	35 ·01	46 ·46	2	4	22 ·60	−0 ·49
*[1 226]	4 949	50 ·60	14 ·89	1	1	22 ·20	−0 ·09
*[1 226]	4 989	50 ·60	38 ·45	2	2	22 ·65	−0 ·54
5 031	5 071	04 ·96	09 ·02	2	4	20 ·45	+1 ·66
5 091	5 146	22 ·55	03 ·51	2	4	21 ·96	+0 ·15
(2 427)	5 192	15 ·29	43 ·43	2	4	22 ·41	−0 ·30
5 287	5 295	48 ·33	27 ·55	2	4	22 ·59	−0 ·48
5 322	5 348	43 ·82	46 ·41	2	4	23 ·34	−1 ·23

Indiscriminate mean = 40° 54′ 22″·11.
Weighted mean = 40 54 22 ·11 ± 0″·13.
$e = \pm 0''\cdot 59$.
35 observations, 16 pairs.
[Reduction to geodetic station + 2″·00.]

9. ROCKY MOUNTAIN SERIES—continued.

(70) *Latitude at Antelope, Utah.* P. A. Welker. Meridian telescope No. 3. October 12–19, 1892. One division of level = 1″·94, a mean of several determinations. One turn of micrometer = 63″·828, from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
7 067	[1 819]	30 ·21	29 ·69	5	8	40 57 40 ·00	+0 ·49
7 164	7 182	36 ·42	52 ·13	5	8	40 ·43	+0 ·06
7 213	7 233	21 ·74	11 ·38	5	8	40 ·65	−0 ·16
7 253	7 320	18 ·49	10 ·02	5	8	40 ·78	−0 ·29
7 345	7 399	08 ·51	23 ·72	6	8	39 ·21	+1 ·28
7 417	7 437	00 ·67	23 ·36	5	8	39 ·94	+0 ·55
7 462	7 503	08 ·95	08 ·49	6	8	41 ·54	−1 ·05
7 607	7 676	42 ·99	18 ·65	6	8	40 ·34	+0 ·15
7 708	7 733	44 ·31	10 ·17	5	8	39 ·89	+0 ·60
(3 719)	7 777	42 ·10	20 ·83	6	8	40 ·76	−0 ·27
*7 823	7 857	25 ·90	52 ·94	5	5	40 ·57	−0 ·08
*7 823	7 874	25 ·90	48 ·12	5	5	40 ·76	−0 ·27
7 893	7 902	11 ·71	37 ·25	5	8	40 ·46	+0 ·03
7 914	[2 058]	22 ·06	22 ·29	5	8	40 ·26	+0 ·23
7 967	7 975	03 ·62	54 ·86	5	8	40 ·51	−0 ·02
8 034	8 124	32 ·90	45 ·90	5	8	40 ·47	+0 ·02
8 162	(3 957	36 ·65	18 ·72	5	8	40 ·81	−0 ·32
8 227	[2 150]	52 ·48	01 ·67	5	2	39 ·68	+0 ·81
*8 296	8 344	46 ·78	43 ·15	5	5	40 ·39	+0 ·10
*8 296	8 366	46 ·78	14 ·75	5	5	40 ·45	+0 ·04
52	100	04 ·91	10 ·69	5	8	41 ·22	−0 ·73
120	*165	52 ·98	20 ·58	5	5	41 ·02	−0 ·53
155	*165	30 ·96	20 ·58	5	5	41 ·09	−0 ·60

Indiscriminate mean = 40° 57′ 40″·49.
Weighted mean = 40 57 40 ·49 ± 0″·07.
$e = \pm 0''{\cdot}35$.
119 observations, 23 pairs.
[Reductiou to geodetic station + 0″·33.]

9. ROCKY MOUNTAIN SERIES—continued.

(71) *Latitude at Promontory, Utah.* P. A. Welker. Meridian telescope No. 3. July 9–14, 1892. One division of level = 1''·94, an average of several determinations at various times. One turn of micrometer = 63''·827, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		"	"			° ' "	"
4 969	4 992	52·06	41·09	5	7	41 17 47·91	+0·37
5 061	5 071	31·01	09·02	5	7	48·35	−0·07
5 147	5 146	40·50	03·51	5	7	49·36	−1·08
5 192	5 248	43·43	32·78	6	8	48·79	−0·51
5 302	5 313	33·25	41·73	6	8	49·12	−0·84
5 348	5 399	46·41	32·74	4	7	48·10	−0·18
5 512	5 527	28·87	04·05	5	7	48·44	−0·16
*5 545	5 563	53·68	38·63	5	4	47·27	+1·01
*5 545	[1 395]	53·68	04·15	5	5	47·37	+0·91
5 708	5 769	24·44	33·05	5	7	48·37	−0·09
5 788	5 871	27·75	11·53	5	7	48·82	−0·54
5 978	(2 812)	33·59	54·63	5	7	48·23	+0·05
6 082	6 109	05·97	37·47	5	7	47·90	+0·38
*6 289	6 300	42·82	19·20	5	5	48·14	+0·14
*6 289	6 322	42·82	48·24	5	5	48·20	+0·08
[1 574]	6 391	12·40	00·82	4	7	47·68	+0·60
6 404	6 473	27·99	07·74	3	7	48·62	−0·34
6 520	6 556	05·64	06·39	5	7	47·93	+0·35
6 583	6 637	29·13	40·85	5	7	47·80	+0·48
6 690	6 748	01·15	45·20	5	7	48·73	−0·45
6 758	6 847	10·82	34·69	5	7	47·73	+0·55

Indiscriminate mean = 41° 17′ 48″·23.
Weighted mean = 41 17 48 ·28 ± 0″·06.
$e = \pm 0''·27$.
103 observations, 21 pairs.
[Reduction to geodetic station − 0″·01.]

9. ROCKY MOUNTAIN SERIES—continued.

(72) *Latitude at Deseret, Utah.* P. A. Welker. Meridian telescope No. 3. September 8–13, 1892. One division of level = 1″·94, a mean of several determinations at various times. One turn of micrometer = 63″·748, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
(2 939)	6 302	41 ·55	51 ·24	5	8	40 27 31 ·91	+0 ·02
6 300	6 348	19 ·20	13 ·54	5	8	32 ·39	−0 ·46
[1 574]	6 392	12 ·40	27 ·60	5	6	31 ·46	+0 ·47
6 428	6 491	21 ·69	30 ·31	5	8	32 ·90	−0 ·97
6 542	6 583	59 ·72	29 ·13	5	8	31 ·31	+0 ·62
6 599	6 656	30 ·76	21 ·14	5	8	32 ·38	−0 ·45
6 697	6 714	01 ·06	28 ·48	4	7	31 ·10	+0 ·83
6 784	6 799	24 ·63	35 ·71	5	8	31 ·31	+0 ·62
6 827	6 847	07 ·02	34 ·69	5	8	31 ·83	+0 ·10
6 858	6 932	03 ·33	05 ·23	5	8	32 ·58	−0 ·65
6 962	*6 998	39 ·91	16 ·72	5	5	32 ·56	−0 ·63
6 965	*6 998	10 ·20	16 ·72	5	5	32 ·55	−0 ·62
7 029	7 062	30 ·37	29 ·57	5	8	31 ·94	−0 ·01
7 091	7 164	39 ·35	36 ·42	5	8	30 ·97	+0 ·96
7 173	7 211	45 ·58	07 ·11	5	8	32 ·25	−0 ·32
7 275	7 310	30 ·00	00 ·96	5	8	31 ·55	+0 ·38
7 333	7 385	11 ·02	55 ·98	5	8	32 ·52	−0 ·59
7 399	7 455	23 ·68	11 ·96	5	8	32 ·26	−0 ·33
7 505	7 544	00 ·40	59 ·27	5	8	31 ·79	+0 ·14
7 676	7 693	18 ·65	38 ·57	4	7	31 ·97	−0 ·04
7 760	7 796	03 ·92	20 ·16	5	8	31 ·50	+0 ·43
7 820	7 843	16 ·33	48 ·53	5	8	31 ·74	+0 ·19

Indiscriminate mean = 40° 27′ 31″·94.
Weighted mean = 40 27 31 ·93 ± 0″·08.
$e = \pm 0''\cdot 48$.
108 observations, 22 pairs.
[Reduction to geodetic station + 0·31.]

Station No. 73. Beaver, Utah. United States Geographical Surveys West of the One hundredth Meridian. Lieut. G. M. Wheeler, United States Engineers, in charge. Washington, 1877. Vol. II, pp. 54–71. Observations for latitude were made on 7 nights in August, 1872, by John H. Clark, using the meridian instrument, Würdemann No. 16. Focal length 26 inches, clear aperture 1¾ inches. Though 30 pairs were used only 94 individual results for latitude were obtained on account of the unfavorable weather. Resulting value for latitude, 38° 16′ 23″·28 ± 0″·06.

9. ROCKY MOUNTAIN SERIES—completed.

(74) *Latitude at Oasis, Utah.* Fremont Morse. Zenith telescope No. 6. August 25–31, 1898. One division of level = 2″·17, determined at office January, 1893. One turn of micrometer = 76″·240, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 817	6 849	36·18	04·92	2	4	39 17 34·12	+1·35
6 930	6 952	12·58	47·52	2	4	35·80	−0·33
(3 354)	(3 361)	47·30	59·94	2	4	36·31	−0·84
6 990	7 027	03·82	01·71	2	4	35·43	+0·04
7 067	7 085	19·13	29·22	3	6	35·84	−0·37
7 171	7 204	03·38	43·01	3	6	35·65	−0·18
(3 475)	7 254	02·97	17·35	3	5	35·83	−0·36
7 255	*(3 503)	25·80	24·42	2	2	35·04	+0·43
*(3 503)	7 276*M*	24·42	50·26	2	2	35·76	−0·29
(3 519)	7 377	01·79	58·56	2	4	55·48	−0·01
(3 553)	7 453	39·61	24·19	4	7	35·98	−0·51
7 505	7 559	24·25	19·65	4	8	34·58	+0·89
7 566	*(3 649)	00·85	36·59	2	3	35·46	+0·01
(3 630)	*(3 649)	43·93	36·59	1	1	35·22	+0·25
7 598	7 607	45·31	03·22	2	4	34·92	+0·55
(3 669)	7 664	50·37	07·74	2	4	35·64	−0·17
7 659	7 686	18·19	20·69	2	4	36·72	−1·25
7 705	7 753	55·97	54·09	5	8	35·13	+0·34
*7 765	*7 765	28·59	28·59	4	8	36·62	−1·15
(3 728)	7 810*P*	48·15	32·62	1	2	34·93	+0·54
*(3 754)	*(3 754)	35·99	35·99	4	5	34·49	+0·98
*7 858	*7 858	42·12	42·12	4	7	34·86	+0·61
†672	*7 932	06·89	58·30	3	0·2	37·60	−2·13
(3 801)	*7 932	15·69	58·30	2	2	35·53	−0·06
(3 802)	*7 932	19·03	58·30	1	1	35·39	+0·08
7 972	(3 843)	47·89	33·96	4	7	35·25	+0·22
7 999	(3 857)	40·05	52·68	4	7	34·71	+0·76
8 070	*8 106	33·20	05·56	4	4	35·66	−0·19
8 078	*8 106	02·24	05·56	4	4	35·81	−0·34
8 188	(3 957)	48·27	19·59	3	4	36·25	−0·78
8 218	8 238	49·85	13·36	1	2	35·59	−0·12
8 276	8 298	05·71	55·48	1	2	35·48	−0·01
(4 022)	(4 032)	42·19	09·82	1	2	35·74	−0·27
8 355	8 370	08·76	17·36	1	2	35·83	−0·36

Indiscriminate mean = 39° 17′ 35″·55.
Weighted mean = 39 17 35 ·47 ± 0″·08.
$e = \pm 0''\cdot 66$.
87 observations, 34 pairs.
[Reduction to geodetic station 0″·00.]

† Weise. XII.

10. NEVADA SERIES.

(75) *Latitude at Ibepah, Utah.* E. P. Austin. Meridian telescope No. 3. August 30 to September 5, 1889. One division of level = 1″·94, a mean of several determinations at various times. One turn of micrometer = 63″·959, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 842	5 871	47·87	00·45	2	3	39 49 39·15	+0·20
5 918	(2 769)	18·63	56·68	1	2	40·21	−0·86
5 978	(2 806)	25·25	41·31	3	4	39·05	+0·30
(2 845)	6 162	06·69	07·29	5	7	39·56	−0·21
6 255	(2 968)	04·07	43·50	6	8	39·84	−0·49
(3 015)	(3 023)	12·45	45·17	5	6	40·09	−0·74
6 463	(3 071)	50·10	28·14	5	6	38·80	+0·55
6 522	6 542	02·03	15·79	5	7	38·16	+1·19
6 612	6 615	01·48	47·68	5	7	39·72	−0·37
6 662	(3 174)	57·22	29·99	5	7	39·24	+0·11
6 698	6 754	57·98	18·35	5	6	40·03	−0·68
6 769	6 813	35·55	46·81	4	5	38·02	+1·33
6 856	6 879	20·34	10·03	5	7	39·95	−0·60
6 928	6 940	44·21	28·61	6	8	39·31	+0·04
6 979	(3 372)	14·23	59·89	6	8	39·46	−0·11
7 037	7 088	29·26	25·13	6	8	39·13	+0·22
7 143	(3 465)	23·64	53·30	6	7	39·07	+0·28
7 213	7 241	01·03	31·71	5	7	39·65	−0·30
(3 491)	7 268	02·57	26·89	3	4	39·24	+0·11
*7 294M	7 368	08·79	41·41	5	5	39·54	−0·19
*7 294M	(3 537)	08·79	33·78	4	4	39·07	+0·28
7 402	7 453	15·79	42·96	5	6	38·84	+0·51
7 493	7 561	35·69	01·15	5	7	39·51	−0·16
*7 605	(3 652	20·62	37·94	5	4	39·55	−0·20
*7 605	(3 659)	20·62	17·93	5	4	39·73	−0·38

Indiscriminate mean = 39° 49′ 39″·36.
Weighted mean = 39 49 39 ·35 ± 0″·07.
$e = \pm 0''·80$.
117 observations, 25 pairs.
[Reduction to geodetic station − 0″·22]

10. NEVADA SERIES—continued.

(76) *Latitude at Pilot Peak, Nevada.* E. P. Austin. Meridian telescope No. 3. July 11–16, 1889. One division of level = 1″·94, a mean of several determinations at various times. One turn of micrometer = 63″·959, from circumpolar observations at Ibepah.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 031	5 071	24 ·35	29 ·72	3	2	41 01 07 ·56	+0 ·70
[1 273]	(2 391)	38 ·03	57 ·38	1	1	08 ·63	−0 ·37
5 143	(2 422)	41 ·15	09 ·64	4	3	08 ·40	−0 ·14
5 192	5 248	08 ·61	59 ·47	3	2	07 ·68	+0 ·58
5 302	5 313	01 ·38	10 ·93	4	3	07 ·92	+0 ·34
5 322	5 348	13 ·26	17 ·32	3	2	08 ·68	−0 ·42
5 459	5 525	32 ·72	05 ·32	5	3	07 ·51	+0 ·75
5 597	5 643	36 ·28	10 ·58	5	3	08 ·46	−0 ·20
5 677	5 752	23 ·48	54 ·01	5	3	08 ·16	+0 ·10
5 776	5 842	34 ·77	47 ·87	4	2	07 ·54	+0 ·72
(2 732)	5 931	25 ·46	41 ·90	5	3	09 ·41	−1 ·15
(2 845)	6 109	06 ·69	36 ·46	5	3	09 ·02	−0 ·76
6 162	6 193	07 ·29	25 ·95	5	3	07 ·47	+0 ·79
6 224	6 245	25 ·47	43 ·51	4	3	08 ·06	+0 ·20
(2 963)	(2 989)	52 ·18	48 ·68	5	3	07 ·37	+0 ·89
6 410	6 438	10 ·42	29 ·62	5	3	08 ·29	−0 ·03
(3 054)	(3 068)	16 ·02	28 ·85	4	3	07 ·55	+0 ·71
6 542	6 601	15 ·79	10 ·69	4	3	08 ·96	−0 ·70
6 640	6 674	53 ·14	34 ·04	5	3	08 ·45	−0 ·19
6 734	(3 233)	08 ·69	09 ·77	4	3	08 ·77	−0 ·51
(3 262)	6 847	33 ·85	02 ·72	5	3	09 ·07	−0 ·81
6 867	6 912	01 ·30	18 ·67	5	3	07 ·95	+0 ·31
(3 338)	6 980	16 ·37	55 ·94	5	3	08 ·76	−0 ·50

Indiscriminate mean = 41° 01′ 08″·25.
Weighted mean = 41 01 08 ·26 ± 0″·09.
$e = \pm 1''·21$.
98 observations, 23 pairs.
[Reduction to geodetic station + 0″·05.]

10. NEVADA SERIES—continued.

(77) *Latitude at Pioche, Nevada.* G. F. Bird. Meridian telescope No. 3. September 13–21, 1883. One division of level = 1″·896, from observations at this station. One turn of micrometer = 63″·793, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 300	6 350	38 ·83	19 ·33	5	6	37 59 07 ·08	−0 ·10
6 427	6 475	59 ·55	27 ·88	5	6	05 ·55	+1 ·43
(3 068)	6 543	56 ·71	28 ·25	5	6	07 ·52	−0 ·54
6 674	6 697	16 ·07	08 ·72	5	6	06 ·19	+0 ·79
6 745	6 784	06 ·42	38 ·38	5	6	06 ·81	+0 ·17
6 827	6 856	29 ·33	16 ·58	5	6	07 ·61	−0 ·63
6 895	6 943	13 ·93	21 ·55	4	5	07 ·33	−0 ·35
6 970	(3 378)	32 ·56	22 ·44	6	6	05 ·65	+1 ·33
7 067	7 112	16 ·52	26 ·45	5	6	07 ·31	−0 ·33
7 194	7 233	25 ·26	09 ·80	6	6	06 ·76	+0 ·22
7 336	7 385	31 ·55	12 ·31	6	6	07 ·65	−0 ·67
7 437	7 468	40 ·13	33 ·58	6	6	07 ·00	−0 ·02
*7 505	*7 505	24 ·04	24 ·04	6	3	07 ·83	−0 ·85
7 560	7 571	38 ·52	32 ·47	5	6	07 ·39	−0 ·41
7 658	7 664	53 ·48	24 ·65	5	6	07 ·12	−0 ·14
7 765	7 777	55 ·09	00 ·81	5	6	07 ·27	−0 ·29
(3 766)	7 855	05 ·24	07 ·82	5	6	06 ·28	+0 ·70
7 880	(3 802)	15 ·32	59 ·42	5	6	07 ·28	−0 ·30
[2 058]	7 945	09 ·98	59 ·23	4	5	07 ·54	−0 ·56
7 958	(3 854)	57 ·40	24 ·01	5	6	06 ·68	+0 ·30
*8 032	8 059	05 ·81	29 ·10	5	4	07 ·33	−0 ·35
*8 032	8 082	05 ·81	58 ·53	5	4	07 ·14	−0 ·16

Indiscriminate mean = 37° 59′ 07″·01.
Weighted mean = 37 59 06 ·98 ± 0″·09.
$e = \pm 0''{\cdot}50$.
113 observations, 22 pairs.
[Reduction to geodetic station − 0″·28.]

10. NEVADA SERIES—continued.

Station No. 78. Pioche, Nevada. United States Geographical Surveys West of the One hundredth Meridian. Lieut. G. M. Wheeler, United States Engineers, in charge. Washington, 1877. Vol. II, pp. 75–96. Observations for latitude were made by W. W. Marryatt on 6 nights in October, 1872, using the meridian instrument, Würdemann No. 16. Focal length 26 inches, clear aperture 1¾ inches. Number of individual results for latitude 193. Resulting value for latitude 37° 55′ 26″·07 ± 0″·07.

(79) *Latitude at Diamond Peak, Nevada.* R. A. Marr. Meridian telescope No. 3. October 1–5, 1881. One division of level = 1″·86. One turn of micrometer = 63″·815, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 397	6 410	59·85	40·56	2	6	39 35 03·82	+0·31
6 491	*6 520	21·92	59·68	3	5	05·03	−0·90
*6 520	6 553	59·68	06·28	3	5	04·53	−0·40
6 623	6 637	02·75	53·91	4	8	04·42	−0·29
6 656	6 667	35·30	12·06	5	8	04·70	−0·57
6 714	6 734	54·21	14·72	5	8	03·16	+0·97
6 748	(3 262)	18·09	45·61	5	8	03·60	+0·53
6 852	6 901	21·72	56·27	5	8	04·06	+0·07
*6 928	6 940	08·52	51·42	5	6	04·84	−0·71
*6 928	6 943	08·52	41·53	5	6	04·74	−0·61
6 979	(3 372)	41·16	27·68	5	8	04·57	−0·44
7 037	7 065	02·02	05·88	5	8	03·93	+0·20
7 086	7 143	50·89	02·02	5	8	04·65	−0·52
7 204	7 233	29·60	36·27	5	8	03·97	+0·16
7 277	7 320	25·71	44·94	4	8	03·36	+0·77
(3 555)	7 444	07·68	12·83	5	8	03·59	+0·54
7 462	7 544	59·75	57·79	5	8	03·90	+0·23
7 733	7 755	22·95	20·39	5	8	04·59	−0·46
7 823	7 881	46·35	12·10	4	8	04·38	−0·25
(3 799)	7 945	19·46	36·82	4	8	04·44	−0·31
7 972	(3 841)	11·79	26·41	4	8	03·68	+0·45
7 997	8 054	08·07	23·16	4	8	03·88	+0·25
8 125	8 141	39·19	21·69	4	8	03·58	+0·55
8 162	8 227	13·14	31·02	4	8	05·04	−0·91
8 268	8 296	38·87	27·00	4	8	03·78	+0·35
8 310	(4 025)	45·96	50·68	3	7	03·96	+0·17

Indiscriminate mean = 39° 35′ 04″·16.
Weighted mean = 39 35 04 ·13 ± 0″·07.
$e = \pm 0''·39$.
112 observations, 26 pairs.
[Reduction to geodetic station − 0″·28.]

10. NEVADA SERIES—continued.

(80) *Latitude at Mount Callahan, Nevada.* R. A. Marr. Meridian telescope No. 3. July 29 to August 2, 1881. One division of level = 1″·86. One turn of micrometer = 63″·866, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 259	5 287	21 ·72	51 ·62	2	5	39 42 31 ·68	+0 ·64
5 388	5 432	09 ·20	20 ·57	5	6	32 ·94	−0 ·62
5 459	5 466	22 ·65	59 ·05	5	6	32 ·74	−0 ·42
5 490	5 628	30 ·10	06 ·99	5	6	32 ·95	−0 ·63
5 659	5 705	47 ·20	56 ·12	5	6	32 ·73	−0 ·41
5 740	5 749	00 ·66	08 ·04	5	6	32 ·26	+0 ·06
5 842	5 871	15 ·27	31 ·11	5	6	31 ·00	+1 ·32
5 911	5 927	22 ·55	07 ·87	5	6	32 ·37	−0 ·05
5 950	5 967	03 ·30	05 ·85	5	6	32 ·43	−0 ·11
(2 795)	6 033	52 ·58	11 ·80	4	6	32 ·62	−0 ·30
6 114	6 123	21 ·37	16 ·87	5	6	32 ·76	−0 ·44
6 193	6 218	32 ·45	34 ·39	4	6	32 ·00	+0 ·32
(2 939)	6 297	01 ·01	33 ·20	5	6	32 ·69	−0 ·37
(2 963)	(2 990)	11 ·02	55 ·50	5	6	31 ·68	+0 ·64
(3 011)	6 452	52 ·09	41 ·81	4	6	31 ·86	+0 ·46
6 491	6 520	21 ·92	59 ·68	5	6	33 ·42	−1 ·10
6 623	6 637	02 ·75	55 ·20	4	6	31 ·32	+1 ·00
6 662	(3 174)	52 ·74	26 ·62	5	6	32 ·28	+0 ·04
6 714	6 734	54 ·21	14 ·37	4	6	31 ·68	+0 ·64
6 745	6 771	21 ·92	56 ·73	5	6	32 ·77	−0 ·45
(3 258)	(3 267)	09 ·70	44 ·58	5	6	32 ·40	−0 ·08
6 856	6 879	35 ·46	28 ·49	5	6	32 ·49	−0 ·17

Indiscriminate mean = 39° 42′ 32″·32.
Weighted mean = 39 42 32 ·32 ± 0″·08.
$e = \pm 0''\cdot 40$.
102 observations, 22 pairs.
[Reduction to geodetic station − 0″·41.]

10. NEVADA SERIES—continued.

(81) *Latitude at Toiyabe Dome, Nevada.* W. Eimbeck and R. A. Marr. Meridian telescope No. 7. September 20–27, 1880. One division of level = 1″·04, from observations at this station. One turn of micrometer = 78″·329, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 583	6 589	41·24	13·65	5	5	38 49 54·33	+0·22
6 615	6 662	45·34	59·62	4	4	53·72	+0·83
6 690	(3 190)	29·39	59·23	5	5	54·21	+0·34
6 740	6 799	20·45	19·31	5	5	54·49	+0·06
6 883	6 928	49·90	19·02	5	5	54·73	−0·18
(3 338)	6 976	50·55	57·05	4	4	53·81	+0·74
(3 378)	(3 391)	56·36	16·86	5	5	53·26	+1·29
[1 819]	7 126	55·25	17·91	4	4	54·23	+0·32
7 194	(3 480)	03·69	35·44	5	5	55·38	−0·83
7 256	7 278	53·15	54·57	4	4	54·58	−0·03
(3 519)	7 310	11·28	48·13	5	5	54·52	+0·03
(3 530)	7 345	46·00	00·39	3	3	56·22	−1·67
7 363	7 405	57·14	12·11	5	5	55·10	−0·55
7 465	7 480	59·49	17·62	5	5	55·66	−1·11
(3 602)	7 568	15·72	56·40	5	5	54·49	+0·06
7 585	7 631	13·67	00·52	3	3	55·11	−0·56
7 712	7 754	50·08	25·39	4	4	54·95	−0·40
*7 832	*7 857	00·20	33·29	4	2	53·65	+0·90
*7 857	*7 868	33·29	07·93	5	2	54·48	+0·07
*7 832	*7 874	00·20	29·24	1	1	53·34	+1·21
*7 874	*7 868	29·24	07·93	1	1	53·38	+1·17

Indiscriminate mean = 38° 49′ 54″·46.
Weighted mean = 38 49 54 ·55 ± 0″·11.
$e = \pm 0''·82$.
87 observations, 21 pairs.
[Reduction to geodetic station − 0″·69.]

10. NEVADA SERIES—continued.

(82) *Latitude at Carson Sink, Nevada.* W. Eimbeck. Meridian telescope No. 7. July 29 to August 2, 1880. One division of level = 1″·04, determined at Toiyabe Dome, September, 1880. One turn of micrometer = 78″·274, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 388	5 432	59·48	11·19	5	7	39 34 58·50	−0·35
5 459	5 466	13·88	50·35	4	6	58·96	−0·81
5 490	5 628	21·20	00·12	4	6	58·04	+0·11
[1 395]	5 740	44·79	55·09	5	7	57·22	+0·93
5 752	(2 669)	06·23	09·41	4	6	58·43	−0·28
(2 722)	(2 732)	22·07	53·85	4	6	57·58	+0·57
5 900	5 918	57·96	50·89	2	4	57·30	+0·85
(2 804)	6 033	50·97	10·45	3	5	57·32	+0·83
6 079	6 134	29·24	28·41	4	6	58·19	−0·04
6 185	6 223	57·20	10·16	4	6	58·49	−0·34
(2 939)	6 297	02·76	35·15	3	5	58·07	+0·08
(2 963)	(2 990)	13·26	58·68	4	6	57·13	+1·02
6 397	6 410	03·60	44·35	4	6	59·22	−1·07
6 491	*6 520	26·67	04·75	3	3	58·89	−0·74
*6 520	6 553	04·75	11·50	4	4	58·63	−0·48
6 623	6 637	09·45	00·75	4	6	57·87	+0·28
6 656	6 667	43·00	19·12	4	6	58·10	+0·05
6 714	6 734	01·72	22·77	2	4	57·55	+0·60
6 748	(3 262)	25·66	54·64	3	5	57·70	+0·45
6 852	6 901	31·09	06·38	4	6	58·01	+0·14
*6 928	6 940	18·78	01·56	4	4	58·90	−0·75
*6 928	6 943	18·78	53·34	4	4	58·13	+0·02
6 979	(3 372)	52·08	38·88	3	5	58·31	−0·16
7 037	7 065	13·41	17·61	3	5	57·46	+0·69
7 086	7 143	02·82	15·00	4	6	59·24	−1·09
7 204	7 233	42·80	49·63	3	5	58·95	−0·80
7 277	7 320	39·46	59·00	3	5	58·10	+0·05

Indiscriminate mean = 39° 34′ 58″·16.
Weighted mean = 39 34 58 ·15 ± 0″·08.
$e = \pm 0''\cdot 68$.

98 observations, 27 pairs.
[Reduction to geodetic station − 0″·47.]

10. NEVADA SERIES—continued.

(83) *Latitude at Carson City, Nevada.* C. H. Sinclair. Meridian telescope No. 2. July 17–20, 1889. One division of level = 0″·91, determined at office March–April, 1888. One turn of micrometer = 65″·856, from several determinations at various stations.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 114	6 101	22 ·94	29 ·90	4	3	39 09 48 ·06	−0 ·87
(2 883	*6 203	35 ·14	41 ·74	4	2	46 ·60	+0 ·59
*6 203	6 235	41 ·74	06 ·86	4	2	45 ·96	+1 ·23
6 251	6 348	49 ·42	21 ·22	4	3	46 ·24	+0 ·95
6 355	6 390	09 ·47	43 ·59	4	3	47 ·28	−0 ·09
6 466	6 473	31 ·32	21 ·26	4	3	47 ·49	−0 ·30
6 520	6 534	20 ·45	14 ·57	4	3	48 ·14	−0 ·95
6 574	6 583	56 ·24	47 ·27	4	3	47 ·16	+0 ·03
6 589	6 640	18 ·89	52 ·00	4	3	47 ·62	−0 ·43
6 698	6 731	58 ·22	02 ·25	4	3	46 ·85	+0 ·34
6 754	6 784	18 ·13	49 ·33	4	3	45 ·56	+1 ·63
6 817	*6 849	57 ·34	29 ·30	4	2	46 ·00	+1 ·19
*6 849	6 857	29 ·30	49 ·39	4	2	46 ·95	+0 ·24
6 897	6 932	47 ·56	36 ·59	4	3	47 ·16	+0 ·03
6 962	*7 029	12 ·40	04 ·66	4	2	47 ·97	−0 ·78
6 965	*7 029	42 ·51	04 ·66	4	2	48 ·64	−1 ·45
7 067	7 085	05 ·83	17 ·08	3	2	47 ·51	−0 ·32
7 112	7 164	13 ·32	14 ·40	4	3	48 ·07	−0 ·88

Indiscriminate mean = 39° 09′ 47″·18.
Weighted mean = 39 09 47 ·19 ± 0″·13.
$e = \pm 0''\cdot 95$.
71 observations, 18 pairs.
[Reduction to dome of capitol − 0″·85.]

10. NEVADA SERIES—continued.

Latitude at Carson City, Nevada. C. H. Sinclair. Zenith telescope No. 6. August 13–15, 1893. One division of level = 2″·17, determined at office January, 1893. One turn of micrometer = 76″·170, from circumpolar observations at other stations.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 860	(2 732)	37·63	39·57	2	6	39 09 47·61	−0·01
5 922	5 937	30·72	09·78	2	6	47·91	−0·31
5 967	*(2 804)	35·01	11·70	2	4	46·72	+0·88
6 005	*(2 804)	31·63	11·70	2	4	47·37	+0·23
6 047	*(2 822)	55·66	34·88	2	4	47·61	−0·01
6 048	*(2 822)	26·06	34·88	2	4	47·32	+0·28
6 114	6 101	24·05	30·83	3	7	48·33	−0·73
(2 883)	*6 203	34·44	37·56	3	5	48·03	−0·43
(2 888)	*6 203	18·66	37·56	3	5	47·73	−0·13
6 251	6 348	43·69	10·87	2	6	47·63	−0·03
(2 982)	(2 990)	35·93	16·06	3	7	47·53	+0·07
(3 031)	*6 456	48·35	43·24	3	5	48·14	−0·54
*6 456	6 473	43·24	03·29	3	5	47·71	−0·11
6 496	(3 074)	37·08	10·79	3	7	46·49	+1·11
6 520	6 534	00·68	55·88	3	7	46·82	+0·78
6 572	6 625	16·29	05·03	2	6	48·79	−1·19
(3 148)	6 656	52·76	14·28	3	7	46·72	+0·88
6 670	6 702	04·18	10·04	3	7	47·97	−0·37
6 722	6 769	33·98	01·64	3	7	48·17	−0·57
6 802	6 836	50·72	16·80	3	7	48·14	−0·54
6 849	6 857	51·94	11·03	3	7	47·87	−0·27
(3 309)	(3 322)	28·40	18·05	3	7	47·45	+0·15
6 918	6 940	04·04	46·74	3	7	47·30	+0·30
6 990	7 027	59·09	58·54	3	7	48·10	−0·50
7 098	7 146	56·20	15·18	3	7	47·19	+0·41
(3 451)	(3 457)	08·20	52·62	3	7	46·87	+0·73

Indiscriminate mean = 39° 09′ 47″·60.
Weighted mean † = 39 09 47 ·60 ± 0″·07.
$e = \pm 0''\cdot 41$.
70 observations, 26 pairs.
[Reduction to dome of capitol − 0″·85.]

† For combined result see synopsis further on.

10 NEVADA SERIES—continued.

(84) *Latitude at Verdi, Nevada.* G. Davidson. Zenith telescope No. 1. July 12–19, 1872. One division of level = 1″·00. One turn of micrometer = 45″·804, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 210	5 244	04 ·34	18 ·00	5	6	39 31 04 ·23	+0 ·47
5 259	5 271	38 ·76	21 ·40	5	6	04 ·99	−0 ·29
5 313	5 399	16 ·20	22 ·00	3	5	04 ·96	−0 ·26
5 426	5 459	01 ·70	02 ·70	4	6	05 ·03	−0 ·33
5 497	5 534	58 ·80	38 ·40	5	6	05 ·70	−1 ·00
5 549	5 624	14 ·75	24 ·54	5	6	05 ·79	−1 ·09
5 618	*5 705	34 ·51	02 ·00	1	2	04 ·45	+0 ·25
5 659	*5 705	49 ·36	02 ·00	6	4	04 ·50	+0 ·20
*5 647	*5 740	47 ·00	10 ·93	1	2	04 ·58	+0 ·12
*5 647	*5 745	47 ·00	58 ·17	1	2	05 ·66	−0 ·96
*5 740	5 753	10 ·93	39 ·37	6	3	04 ·46	+0 ·24
*5 740	*5 757	10 ·93	47 ·15	1	2	04 ·01	+0 ·69
*5 745	*5 757	58 ·17	47 ·15	5	3	05 ·73	−1 ·03
5 765	5 823	52 ·40	39 ·70	6	6	05 ·90	−1 ·20
5 863	5 871	55 ·84	57 ·71	7	6	05 ·19	−0 ·49
5 900	5 918	32 ·30	25 ·24	5	6	04 ·23	+0 ·47
5 986	6 036	43 ·15	34 ·15	5	6	03 ·91	+0 ·79
6 056	6 147	13 ·15	17 ·80	5	6	04 ·59	+0 ·11
6 237	6 255	02 ·20	32 ·56	4	6	04 ·41	+0 ·29
6 357	6 391	38 ·20	10 ·92	5	6	04 ·60	+0 ·10
6 438	6 496	37 ·74	15 ·50	5	6	05 ·63	−0 ·93
6 516	6 534	45 ·36	43 ·40	1	3	03 ·40	+1 ·30
6 520	6 553	44 ·34	55 ·65	4	6	04 ·28	+0 ·42
6 574	6 601	34 ·28	55 ·02	6	6	04 ·90	−0 ·20
6 623	6 637	01 ·50	53 ·39	5	6	04 ·72	−0 ·02
6 656	6 667	36 ·16	15 ·50	6	6	04 ·89	−0 ·19
6 690	6 697	27 ·12	31 ·60	6	6	04 ·56	+0 ·14
*6 714	6 730	03 ·20	51 ·50	5	4	03 ·58	+1 ·12
*6 714	6 734	03 ·20	29 ·12	5	4	03 ·44	+1 ·26
6 754	6 784	40 ·29	07 ·90	1	3	04 ·18	+0 ·52
6 772	6 808	48 ·96	32 ·66	4	6	04 ·70	0 ·00
6 819	6 834	19 ·50	12 ·10	5	6	03 ·76	+0 ·94
6 852	6 901	46 ·50	27 ·11	5	6	04 ·73	−0 ·03
*6 928	6 940	44 ·30	26 ·34	1	2	03 ·63	+1 ·07
*6 928	6 943	44 ·30	15 ·30	3	3	04 ·29	+0 ·41
6 937	6 963	08 ·03	29 ·73	1	3	05 ·99	−1 ·29
6 983	7 029	40 ·61	17 ·90	4	6	05 ·13	−0 ·43
*6 996	7 001	57 ·08	44 ·54	1	2	05 ·27	−0 ·57
*6 996	7 008	57 ·08	57 ·56	1	2	04 ·75	−0 ·05
7 061	7 101	44 ·70	47 ·23	5	6	04 ·75	−0 ·05
7 122	7 185	00 ·34	30 ·60	5	6	04 ·96	−0 ·26
7 204	7 233	29 ·00	35 ·00	5	6	04 ·61	+0 ·09
7 260	7 313	00 ·03	42 ·57	5	6	03 ·60	+1 ·10
7 401	7 437	22 ·80	26 ·15	1	3	05 ·14	−0 ·44

Indiscriminate mean = 39° 31′ 04″·68.
Weighted mean = 39 31 04 ·70 ± 0″·07.
$e = \pm 0''\cdot 42$.

175 observations, 44 pairs.

[Reduction to geodetic station 0″·00.]

10. NEVADA SERIES—continued.

(85) *Latitude at Lake Tahoe Southeast, California.* C. H. Sinclair. Zenith telescope No. 6. August 16–20, 1893. One division of level = 2″·172, determined at office January, 1893. One turn of micrometer = 76″·172, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 940	5 972	26·55	48·88	4	12	38 57 19·88	−0·12
6 005	(2 804)	31·63	11·72	5	13	20·71	−0·95
6 069	6 114	47·66	24·06	5	13	19·92	−0·16
6 109	(2 874)	37·80	43·58	5	13	19·31	+0·45
(2 888)	(2 898)	18·69	50·38	5	13	19·35	+0·41
*6 246	(2 949)	57·35	07·43	5	9	19·82	−0·06
*6 246	(2 950)	57·35	52·18	5	9	19·77	−0·01
*6355	(2 996)	56·74	25·91	5	9	19·46	+0·30
*6 355	6 391M	56·74	57·19	5	9	19·76	0·00
(3 015)	(3 018)	57·59	13·85	5	6	20·76	−1·00
6 478	6 471	32·65	17·90	5	13	20·07	−0·31
6 563	6 597	07·60	32·58	5	13	19·41	+0·35
6 615	6 662	22·02	29·62	5	13	19·97	−0·21
6 670	6 702	04·18	10·04	5	13	19·97	−0·21
(3 193)	6 715	43·33	24·35	4	12	19·80	−0·04
6 731	6 784	31·40	16·40	5	13	19·10	+0·66
6 834	6 868	59·01	33·06	5	13	19·38	+0·38
6 926	(3 331)	53·94	09·16	5	13	19·78	−0·02
(3 338)	6 976	34·52	34·66	5	13	19·61	+0·15
(3 370)	7 008	44·70	03·36	5	11	19·44	+0·32
7 022	7 061	08·58	39·33	5	13	20·20	−0·44
7 098	7 149	56·24	55·13	5	13	19·59	+0·17

Indiscriminate mean = 38° 57′ 19″·78.
Weighted mean = 38 57 19 ·76 ± 0″·06.
$e = \pm 0''\cdot 35$.
108 observations, 22 pairs.
[Reduction to geodetic station 0″·00.]

10. NEVADA SERIES—continued.

(86) *Latitude at Mount Conness, California.* F. Morse, J. J. Gilbert, and I. Winston. Zenith telescope No. 1. August 13 to September 5, 1890. One division of level = 0″·92, determined at San Francisco, 1891. One turn of micrometer = 47″·52, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
6 300	6 350	23·80	01·42	6	9	37 57 57·14	−0·70
6 355	6 392	06·26	34·76	4	7	55·17	+1·27
(3 015)	6 438	08·74	25·51	6	9	56·11	+0·33
6 475	6 553	54·81	16·93	7	9	56·21	+0·23
6 625	(3 149)	23·52	36·37	7	9	55·89	+0·55
6 674	6 697	26·91	16·15	7	9	56·07	+0·37
6 745	6 784	09·22	41·02	5	8	56·30	+0·14
6 836	6 833	44·34	03·26	8	10	56·20	+0·24
6 867	6 868	51·77	01·96	7	9	56·47	−0·03
6 901	6 976	25·94	07·40	7	9	56·55	−0·11
6 990	7 061	32·22	14·44	6	9	57·19	−0·75
7 126	7 182	14·57	17·74	9	10	56·08	+0·36
7 194	7 233	54·06	37·84	9	10	56·27	+0·17
7 320	*7 385	38·22	26·38	9	7	57·39	−0·95
7 336	*7 385	28·82	26·38	9	7	57·14	−0·70
7 428	(3 594)	40·32	44·30	8	10	56·44	0·00
7 560	7 571	44·49	37·65	8	10	56·39	+0·05
7 631	(3 660)	12·95	57·14	8	10	56·56	−0·12
7 700M	7 796	29·33	56·21	8	10	56·11	+0·33
(3 766)	7 855	57·18	58·92	8	10	56·07	+0·37
7 880	(3 802)	05·94	48·48	7	9	56·61	−0·17
7 958	(3 854)	45·17	08·72	8	10	56·93	−0·49
8 032	8 059	50·05	12·70	7	9	56·16	+0·28
8 107	8 131	47·19	42·43	8	10	56·24	+0·20
8 188	8 227	26·85	32·28	7	9	56·36	+0·08
8 296	8 322	26·76	23·64	7	9	55·77	+0·67
4	(19)	01·02	35·78	8	10	56·38	+0·06
(34)	120	57·05	32·75	8	10	56·41	+0·03
164	197	08·48	18·80	8	10	56·84	−0·40
218	247	03·53	30·12	6	9	57·30	−0·86
(165)	365	13·53	56·32	8	10	56·87	−0·43

Indiscriminate mean = 37° 57′ 56″·44.
Weighted mean = 37 57 56 ·44 ± 0″·06.
$e = \pm 0''·51$.
228 observations, 31 pairs.
[Reduction to geodetic station + 3″·34.]

10. NEVADA SERIES—continued.

(87) *Latitude at Round Top, California.* B. A. Colonna. Zenith telescope No. 1. August 23–29, 1879. One division of level = 0″·94. One turn of micrometer = 47″·521, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n	w	Latitude.	v
		″	″			° ′ ″	″
5 931	5 975	14 ·04	36 ·17	6	6	38 39 47 ·49	−0 ·60
5 996	(2 797)	50 ·62	52 ·28	5	6	47 ·50	−0 ·61
(2 812)	6 079	35 ·85	28 ·57	6	4	46 ·08	+0 ·81
6 129	6 150	26 ·97	11 ·41	6	6	46 ·32	+0 ·57
*6 193	*6 193	33 ·96	33 ·96	6	4	45 ·78	+1 ·11
(2 926)	6 316	44 ·18	41 ·15	6	6	46 ·24	+0 ·65
*6 355	*6 355	41 ·20	41 ·20	6	4	46 ·07	+0 ·82
6 397	6 463	07 ·39	33 ·10	6	6	47 ·03	−0 ·14
6 496	(3 078)	42 ·32	52 ·06	5	6	47 ·27	−0 ·38
6 615	6 662	51 ·70	05 ·99	6	6	46 ·63	+0 ·26
6 690	6 734	36 ·75	30 ·59	6	6	46 ·89	0 ·00
6 771	6 817	13 ·85	26 ·95	5	6	47 ·56	−0 ·67
(3 267)	(3 294)	02 ·57	37 ·47	6	6	47 ·08	−0 ·19
6 879	6 895	47 ·98	53 ·40	6	6	47 ·58	−0 ·69
6 928	6 979	29 ·32	03 ·21	6	6	47 ·12	−0 ·23
*7 001	*7 001	26 ·58	26 ·58	6	4	48 ·06	−1 ·17
7 086	(3 445)	14 ·78	30 ·12	6	6	46 ·98	−0 ·09
7 174	7 213	57 ·01	12 ·20	6	6	46 ·08	+0 ·81
7 256	7 294	06 ·89	26 ·87	5	6	46 ·86	+0 ·03
7 336	7 398	41 ·60	43 ·06	6	6	47 ·38	−0 ·49
7 474	7 555	26 ·92	40 ·28	6	6	46 ·78	+0 ·11
7 595	7 606	14 ·23	35 ·02	6	6	46 ·31	+0 ·58
7 686	7 689	45 ·56	56 ·00	6	6	46 ·88	+0 ·01
7 721	(3 719)	05 ·82	32 ·89	6	6	46 ·82	+0 ·07

Indiscriminate mean = 38° 39′ 46″·87.
Weighted mean = 38 39 46 ·89 ± 0″·08.
$e = \pm 0''·51$.
140 observations, 24 pairs.
[Reduction to geodetic station + 0″·01.]

10. NEVADA SERIES—continued.

(88) *Latitude at Mount Lola, California.* B. A. Colonna. Zenith telescope No. 1. July 3–9, 1879. One division of level = 0″·94, determined at the station. One turn of micrometer = 47″·486, from latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n	w	Latitude.	v
		″	″			° ′ ″	″
4 847	4 874	44·12	18·74	2	5	39 25 57·38	+0·62
4 930	955	14·63	06·65	6	4	58·13	−0·13
5 026	5 076	52·16	08·77	6	9	58·69	−0·69
5 131	5 177	53·67	10·78	7	10	57·55	+0·45
5 249	5 284	34·20	32·63	7	10	57·64	+0·36
5 319	5 388	50·20	49·79	6	9	57·98	+0·02
5 440	5 461	58·60	18·82	6	9	57·81	+0·19
5 497	5 534	58·86	34·41	4	7	58·79	−0·79
5 568	5 604	27·44	37·50	6	9	58·35	−0·35
5 647	5 740	34·04	49·04	6	9	58·77	−0·77
(2 717)	5 874	49·95	21·00	7	10	56·93	+1·07
5 900	5 918	53·81	47·86	6	9	57·96	+0·04
6 021	6 052	27·41	23·00	7	10	57·89	+0·11
(2 883)	6 203	36·80	52·06	6	9	58·03	−0·03
6 237	6 255	51·88	19·91	7	10	58·21	−0·21
6 300	6 368	47·45	58·12	5	8	58·60	−0·60
6 392	6 404	13·92	14·33	7	10	58·75	−0·75
6 497	6 520	22·42	10·10	7	10	57·39	+0·61
6 574	6 601	53·93	12·12	6	9	57·87	+0·13
6 635	6 657	55·09	17·37	7	10	58·00	0·00
6 690	6 723	36·75	21·14	7	10	57·62	+0·38
6 754	6 784	41·06	10·87	6	9	57·66	+0·34
6 852	6 858	40·35	07·68	7	10	57·88	+0·12
6 913	6 952	25·50	11·75	7	10	58·51	−0·51
6 983	7 029	25·16	59·10	7	10	57·87	+0·13

Indiscriminate mean = 39° 25′ 58″·01.
Weighted mean = 39 25 58·00 ± 0″·07.
$e = \pm 0''·54$.
155 observations, 25 pairs.
[Reduction to geodetic station − 0″·22.]

10. NEVADA SERIES—continued.

(89) *Latitude at Mocho, California.* P. A. Welker. Meridian telescope No. 16. September 18–26, 1887. One division of level = 2″·58, determined in 1882. One turn of micrometer = 67″·317, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
7 493	7 547	07 ·24	03 ·93	7	17	37 28 36 ·97	−0 ·03
7 567	7 582	04 ·91	17 ·46	7	17	36 ·31	+0 ·63
7 641	7 658	36 ·16	44 ·96	7	17	36 ·69	+0 ·25
*7 664	7 699	16 ·41	47 ·95	7	17	36 ·91	+0 ·03
*7 664	7 707	16 ·41	56 ·10	7	17	37 ·16	−0 ·22
7 721	*7 770	46 ·21	23 ·25	7	17	36 ·72	+0 ·22
7 731	*7 770	33 ·81	23 ·25	7	17	36 ·84	+0 ·10
7 798	7 845	18 ·67	17 ·09	7	17	37 ·42	−0 ·48
7 893	(3 799)	44 ·57	28 ·65	6	16	36 ·90	+0 ·04
7 967	7 971	37 ·98	56 ·60	7	17	36 ·69	+0 ·25
8 039	8 051	59 ·55	03 ·05	7	17	36 ·56	+0 ·38
8 106	8 127	41 ·20	07 ·74	7	17	36 ·39	+0 ·55
8 141	8 237	24 ·26	30 ·39	7	17	37 ·48	−0 ·54
8 299	8 310	26 ·33	45 ·87	7	17	36 ·44	+0 ·50
(4 028)	(4 038)	14 ·68	07 ·78	7	17	36 ·66	+0 ·28
(4 052)	7	31 ·00	25 ·03	7	17	36 ·70	+0 ·24
26	46	41 ·04	41 ·14	7	17	36 ·88	+0 ·06
102	(66)	47 ·60	49 ·12	7	17	37 ·27	−0 ·33
126	142	31 ·36	01 ·23	7	17	37 ·36	−0 ·42
164	189	07 ·23	37 ·81	7	17	37 ·17	−0 ·23
213	228	33 ·49	04 ·71	7	17	37 ·61	−0 ·67
267	330	08 ·14	39 ·77	7	17	37 ·37	−0 ·43
395	487	48 ·80	40 ·78	7	17	36 ·75	+0 ·19
499	518	55 ·71	04 ·53	7	17	37 ·26	−0 ·32
558	577	45 ·31	41 ·09	7	17	36 ·77	+0 ·17
628	691	47 ·00	00 ·71	7	17	37 ·40	−0 ·46
706	710	31 ·41	46 ·33	7	17	36 ·73	+0 ·21

Indiscriminate mean = 37° 28′ 36″·94.
Weighted mean = 37 28 36 ·94 ± 0″·05.
$e = \pm 0''\cdot 44$.
188 observations, 27 pairs.
[Reduction to geodetic station 0″·00.]

10. NEVADA SERIES—continued.

(90) *Latitude at Marysville, California.* C. H. Sinclair. Meridian telescope No. 1. May 28 to June 2, 1898. One division of level = 1″·901, determined at office April, 1893. One turn of micrometer = 66·029, from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
4 235	(1 979)	18·22	14·88	5	12	39 08 12·71	−0·23
4 271	4 302	08·35	10·27	5	18	12·92	−0·44
4 328	*4 335	01·74	12·03	5	15	12·24	+0·24
*4 335	4 387	12·03	58·04	5	14	12·18	+0·30
*4 433	*4 479	25·55	00·41	4	7	12·72	−0·24
*4 433	*4 536	25·55	42·60	4	8	12·45	+0·03
*4 467	*4 479	50·78	00·41	4	6	12·31	+0·17
*4 467	*4 536	50·78	42·60	4	6	12·04	+0·44
4 552	4 596	10·95	59·86	3	11	12·34	+0·14
4 615	(2 155)	46·34	07·76	3	12	12·22	+0·26
4 696	4 751	12·05	30·64	5	17	13·07	−0·59
4 758	4 812	15·02	44·29	4	13	12·22	+0·26
(2 255)	(2 265)	09·19	13·70	5	13	12·36	+0·12
4 870	4 906	33·33	34·43	5	14	12·38	+0·10

Indiscriminate mean = 39° 08′ 12″·44.
Weighted mean = 39 08 12 ·48 ± 0″·06.
$e = \pm 0''\!\cdot\!44$.
61 observations, 14 pairs.
[Reduction to court-house + 10″·05.]

10. NEVADA SERIES—continued.

(91) *Latitude at Mount Hamilton,*† *California.* C. H. Sinclair. Meridian telescope No. 2. November 21–28, 1888. One division of level = 0″·91, determined at office March-April, 1888. One turn of micrometer = 65″·856, a mean of several determinations.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
8 224	*8 256	55·27	31·76	2	0·6	37 20 28·72	+0·38
*8 256	8 261	31·76	05·90	2	0·6	28·36	+0·74
(4 057)	36	29·11	03·94	2	0·9	28·69	+0·41
(43)	100	17·07	31·17	1	0·5	30·34	−1·24
121	170	46·04	34·01	2	0·9	27·64	+1·46
285	318	50·14	17·66	1	0·5	27·34	+1·76
*349	404	18·24	30·20	1	0·4	25·99	+3·11
*349	432	18·24	18·77	1	0·4	26·44	+2·66
453	515	54·53	50·48	1	0·5	30·91	−1·81
*561	588	41·84	27·20	3	0·8	30·51	−1·41
*561	610	41·84	23·30	1	0·4	30·90	−1·80
628	691	29·40	43·80	3	1·3	30·41	−1·31
707	721	02·47	03·07	4	1·5	28·38	+0·72
744	760	06·77	32·57	3	1·3	29·10	0·00
*(381)	871	42·13	34·86	4	1·0	31·21	−2·11
*(381)	888	42·13	09·39	4	1·0	30·93	−1·83
967	(489)	03·67	39·23	5	1·7	29·12	−0·02
1 040	1 129	44·48	17·30	4	1·5	28·30	+0·80
1 071	{(537), (538) M}	32·19	39·35	3	1·3	30·08	−0·98
1 139	1 175	34·19	09·82	4	1·5	29·14	−0·04
1 203	1 241	26·12	36·62	4	1·5	28·79	+0·31
*1 293	1 316	13·68	42·59	4	1·0	29·10	0·00
*1 293	1 324	13·68	52·04	4	1·0	29·32	−0·22
1 363	1 425	25·09	41·00	4	1·5	27·66	+1·44
1 445	*(772)	57·74	29·42	2	0·6	32·37	−3·27
*(772)	1 540	29·42	36·49	2	0·6	28·44	+0·66
1 549	[503]	00·14	37·57	3	1·3	27·80	+1·30

Indiscriminate mean = 37° 20′ 29″·11.
Weighted mean = 37 20 29 ·10 ± 0″·17.
$e = \pm 1''·27$.
74 observations, 27 pairs.

† The United States Coast and Geodetic Survey latitude station on the mount is 3″·51 north and 16″·36 east of the Transit House (or meridian) of the Lick Observatory. The instrument was found to be in a very defective condition, and it is hoped the latitude will be reobserved.

Addition to foot note, July 16, 1900: Volume IV of the publications of the Lick Observatory (Sacramento, Cal., 1900) came to hand as this paper was passing through the press. R. H. Tucker, astronomer at the observatory, gives the following results for latitude of the Meridian Circle made during the years 1893–94–95–96:

From 36 stars at U. C.	37° 20′ 25″·49
From 41 stars at L. C.	·49
From 32 stars at both culminations	·52
From 86 equatorial stars	·65
From 22 zenithal stars	·77

The resulting normal latitude φ_n as corrected for variations of pole (answering to the epoch 1895–97) and derived from about 1 000 observations of 77 culminations of 45 circumpolar stars and from about 1 400 observations of 86 equatorial stars is given as 37° 20′ 25″·57 ± 0″·02 (p. 301).

To compare this result with that obtained by the Coast and Geodetic Survey we have the geodetically determined difference of latitude between the Survey station and the Lick Transit House or of the Meridian Circle, derived from

10. NEVADA SERIES—continued.

(92) *Latitude at Yolo Base Southeast, California.* J. J. Gilbert. Zenith telescope No. 1. July 24–30, 1880. One division of level = 0″·94, determined at Mount Lola, California, July, 1879. One turn of micrometer = 47″·416, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 834	*5 874	17·47	24·35	6	5	38 31 34·21	+0·37
*5 874	5 895	24·35	26·70	7	5	33·95	+0·63
5 911	5 931	19·52	16·49	7	7	33·85	+0·73
5 962	5 990	23·80	45·16	7	7	34·19	+0·39
5 996	(2 797)	52·63	54·08	7	7	34·78	−0·20
6 033	6 091	10·38	47·40	7	7	34·76	−0·18
6 129	6 150	26·98	11·18	7	7	34·66	−0·08
(2 898)	6 235	58·95	19·48	7	7	35·22	−0·64
†2 646	6 427	35·30	11·43	7	7	35·81	−1·23
6 463	(3 048)	28·92	37·66	7	7	35·42	−0·84
6 542	6 623	03·55	08·94	7	7	34·72	−0·14
6 640	6 654	52·75	08·23	7	7	34·17	+0·41
*6 711	*6 711	55·51	55·51	7	4	34·43	+0·15
6 745	6 777	30·10	43·90	7	7	35·70	−1·12
6 817	6 875	18·08	08·23	7	7	34·02	+0·56
6 928	6 979	18·76	52·08	7	7	34·85	−0·27
(3 393)	7 064	50·77	23·24	7	7	35·11	−0·53
7 086	(3 445)	02·80	17·62	7	7	34·35	+0·23
7 200	7 220	26·40	37·33	7	7	34·51	+0·07
7 246	7 278	05·76	54·58	7	7	33·90	+0·68
7 320	7 398	59·00	27·97	7	7	34·27	+0·31
7 465	7 501	59·65	40·40	7	7	33·83	+0·75
7 520	7 582	14·60	11·84	7	7	34·48	+0·10
7 611	7 664	16·74	16·08	7	7	34·66	−0·08
7 686	7 689	28·44	38·56	7	7	34·19	+0·39
7 733	7 782	40·66	41·88	7	7	34·65	−0·07

Indiscriminate mean = 38° 31′ 34″·56.
Weighted mean = 38 31 34 ·58 ± 0″·07.
$e = \pm 0''{\cdot}31$.
181 observations, 26 pairs.
[Reduction to geodetic station − 0″·45.]

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measures by Assistant R. A. Marr in 1888, viz: 3″·51, the Lick Observatory reference point being south of the Survey station. Hence we have—

φ Coast and Geodetic Survey station, 1888	37° 20′ 29″·10 ± 0″·17
Same when corrected for variations of pole	29 ·06
Δφ	− 3 ·51
φ_0 Lick Observatory Meridian Circle	37 20 25 ·55

showing a very close agreement, notwithstanding that the two stations are about 400 metres apart, with a surface depression between them and a possible differential deflection.

In the above results the reduction to sea level (−0″·21) is *not* included. C. A. S.

†Groombridge.

10. NEVADA SERIES—completed.

(93) *Latitude at Yolo Base Northwest, California.* E. F. Dickins. Zenith telescope No. 1. August 28 to September 3, 1880. One division of level = 0″·94, from observations at Mount Lola July, 1879. One turn of micrometer = 47″·424, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
*6 193	*6 193	33 ·15	33 ·15	4	4	38 40 36 ·56	+0 ·73
(2 926)	6 316	42 ·68	38 ·96	7	8	37 ·37	−0 ·08
*6 355	*6 355	38 ·05	38 ·05	7	4	37 ·62	−0 ·33
G 2 646	6 427	36 ·88	11 ·33	7	8	38 ·06	−0 ·77
6 463	(3 048)	28 ·92	37 ·66	7	8	37 ·43	−0 ·14
6 496	(3 078)	37 ·65	47 ·06	7	8	37 ·20	+0 ·09
6 542	6 551	03 ·55	14 ·40	7	8	36 ·27	+1 ·02
6 644	6 662	40 ·43	59 ·10	7	8	37 ·33	−0 ·04
6 745	6 777	30 ·10	43 ·90	7	8	37 ·91	−0 ·62
(3 267)	(3 294)	53 ·43	27 ·86	7	8	37 ·07	+0 ·22
6 879	6 895	38 ·23	43 ·54	7	8	37 ·95	−0 ·66
6 928	6 979	18 ·76	52 ·08	7	8	37 ·44	−0 ·15
7 084	7 114	03 ·95	53 ·24	7	8	37 ·84	−0 ·55
7 174	7 213	44 ·29	59 ·12	7	8	37 ·03	+0 ·26
7 256	7 294	53 ·38	13 ·09	7	8	37 ·78	−0 ·49
7 313	7 336	49 ·33	24 ·07	7	8	37 ·99	−0 ·70
(3 565)	7 503	47 ·58	17 ·79	7	8	37 ·35	−0 ·06
7 548	7 568	40 ·76	57 ·10	7	8	36 ·37	+0 ·92
7 595	7 606	57 ·67	18 ·45	7	8	37 ·18	+0 ·11
7 686	7 689	28 ·44	38 ·56	7	8	37 ·34	−0 ·05
7 721	*(3 719)	48 ·35	15 ·30	7	5	36 ·66	+0 ·63
7 731	*(3 719)	36 ·49	15 ·30	7	5	36 ·43	+0 ·86
7 798	7 855	24 ·75	03 ·00	7	8	36 ·90	+0 ·39
7 880	7 901	10 ·90	26 ·40	7	8	37 ·66	−0 ·37
[2 058]	7 958	08 ·80	54 ·33	7	8	37 ·17	+0 ·12
(3 843)	8 023	19 ·06	07 ·60	7	8	36 ·55	+0 ·74
8 052	8 107	44 ·51	00 ·26	7	8	37 ·65	−0 ·36

Indiscriminate mean = 38° 40′ 37″·26.
Weighted mean = 38 40 37 ·29 ± 0″·07.
$e = \pm 0''{\cdot}43$.
186 observations, 27 pairs.
[Reduction to geodetic station − 0″·13.]

II. WESTERN OR COAST RANGE SERIES.

(94) *Latitude at Mount Diablo, California.* W. Eimbeck. Zenith telescope No. 1. July 27 to August 6, 1876. One division of level = 0″·933, determined at San Francisco March, 1877. One turn of micrometer = 45″·820, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
5 795	5 828	59·13	47·89	5	11	37 52 50·03	−0·40
5 853	5 922	30·43	40·82	5	11	49·46	+0·17
5 999	6 052	19·55	19·97	5	11	49·52	+0·11
6 087	6 109	57·67	31·66	6	11	48·99	+0·64
(2 874)	6 162	45·73	09·71	6	11	50·50	−0·87
6 223	6 246	15·33	21·36	6	9	50·10	−0·47
6 289	(2 963)	14·64	22·21	6	11	49·05	+0·58
6 322	6 350	27·34	38·35	5	11	50·52	−0·89
6 365	6 392	49·74	24·53	5	11	49·47	+0·16
(3 048)	6 496	55·33	56·32	4	10	49·02	−0·29
6 528	6 555	10·05	30·57	5	11	49·27	+0·36
6 602	6 623	47·34	34·86	6	11	49·39	+0·24
6 637	6 659	28·07	13·36	6	11	49·38	+0·25
6 674	6 697	05·64	01·47	5	11	49·26	+0·37
6 741	6 762	07·49	36·15	5	11	49·83	−0·20
6 824	6 866	33·32	06·01	6	11	50·18	−0·55
6 901	6 924	47·58	00·11	6	11	49·96	−0·33
6 944	6 985	25·40	54·34	6	11	49·46	+0·17
7 022	7 073	21·74	29·66	6	11	49·87	−0·24
[1 819]	7 143	43·65	04·75	5	11	49·28	+0·35
7 173	7 220	08·92	32·86	5	11	49·13	+0·50
7 262	7 275	28·39	09·95	6	11	49·39	+0·24

Indiscriminate mean = 37° 52′ 49″·63.
Weighted mean = 37 52 49 ·63 ± 0″·06.
$e = \pm 0''\cdot 37$.
120 observations, 22 pairs.
[Reduction to geodetic station + 0″·03.]

II. WESTERN OR COAST RANGE SERIES—continued.

(95) *Latitude at Vaca, California.* J. S. Lawson. Zenith telescope No. 1. November 4–11, 1880. One division of level = 0″·942, determined at Mount Lola, July, 1879. One turn of micrometer = 47″·456, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
7 664	7 700	16·08	23·30	7	9	38 22 23·60	−0·17
7 733	7 754	40·50	25·30	7	9	23·67	−0·24
7 778	7 807	16·10	27·80	7	9	23·96	−0·53
7 823	7 896	05·50	46·66	6	9	22·96	+0·47
7 902	7 912	21·04	35·11	7	9	23·73	−0·30
7 937	7 953	56·40	59·64	7	8	23·75	−0·32
7 967	8 003	50·16	43·20	7	9	23·76	−0·33
8 032	8 036	04·54	00·14	7	9	22·76	+0·67
8 071	8 124	40·60	41·56	7	9	23·99	−0·56
8 147	8 158	55·68	23·27	7	9	23·11	+0·32
8 177	8 217	48·19	15·91	7	9	23·77	−0·34
8 282	8 299	12·65	46·46	7	9	23·41	+0·02
8 316	8 324	58·18	32·25	7	9	23·42	+0·01
†6 258	8 354	32·75	51·49	6	9	24·25	−0·82
8	18	18·52	39·80	7	9	23·68	−0·25
55	*80	06·49	02·74	7	6	23·39	+0·04
63	*80	54·56	02·74	7	6	23·33	+0·10
100	120	11·01	51·60	7	9	22·66	+0·77
138	154	31·62	08·74	6	9	23·68	−0·25
166	189	45·46	55·52	7	9	23·95	−0·52
223	239	27·60	03·70	7	9	23·14	+0·29
(165)	(191)	26·31	42·29	7	9	23·46	−0·03
374	393	58·76	12·00	7	9	24·40	−0·97
413	416	26·80	20·21	7	9	23·71	−0·28
450	476	29·80	10·20	7	9	23·19	+0·24
509	*538	32·30	20·34	7	6	22·45	+0·98
515	*538	17·39	20·34	7	6	22·48	+0·95
*566	579	47·85	41·18	7	6	23·22	+0·21
*566	580	47·85	15·48	7	6	22·81	+0·62
614	648	36·94	20·87	7	9	23·18	+0·25
675	706	36·69	28·85	7	9	23·38	+0·05
744	755	18·39	32·62	7	9	22·72	+0·71

Indiscriminate mean = 38° 22′ 23″·41.
Weighted mean = 38 22 23 ·43 ± 0″·06.
$e = \pm 0''·45$.
221 observations, 32 pairs.
[Reduction to geodetic station + 0″·37.]

† Number 6 258 of Radcliffe Catalogue of 1845.

II. WESTERN OR COAST RANGE SERIES—continued.

(96) *Latitude at Monticello, California.* J. S. Lawson. Zenith telescope No. 1. October 3–13, 1880. One division of level = 0″·942, determined at Mount Lola, July, 1879. One turn of micrometer = 47″·396, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
(3 415)	[1 819]	59·58	55·25	5	4	38 39 45·93	+0·53
7 125	7 211	24·90	44·18	4	4	45·23	+1·23
7 256	7 294	53·38	13·09	7	4	47·52	−1·06
7 313	7 336	49·33	24·04	6	4	46·81	−0·35
(3 565)	7 503	47·58	17·79	7	4	46·40	+0·06
7 548	7 568	40·76	57·10	6	4	44·79	+1·67
7 595	7 606	57·67	18·45	7	4	46·36	+0·10
7 686	7 689	28·44	38·56	7	4	46·37	+0·09
7 721	(3 719)	48·35	15·30	7	4	45·86	+0·60
7 798	7 855	24·75	03·01	6	4	45·81	+0·65
7 880	7 901	10·90	26·40	6	4	46·33	+0·13
[2 058]	7 958	08·80	54·33	7	4	46·09	+0·37
(3 843)	8 023	19·06	07·60	7	4	45·21	+1·25
8 052	8 107	44·51	00·26	8	4	47·27	−0·81
8 153	8 227	27·62	51·47	7	4	47·08	−0·62
8 248	8 279	49·50	08·92	6	4	45·99	+0·47
8 307	8 350	41·43	11·40	7	4	47·82	−1·36
8 372	32	56·76	38·23	7	4	47·48	−1·02
89	125	21·00	50·12	7	4	46·67	−0·21
153	178	49·56	44·99	6	4	46·96	−0·50
214	244	38·98	39·20	7	4	45·91	+0·55
264	314	50·03	08·75	6	4	46·30	+0·16
334	377	57·83	37·54	7	4	46·99	−0·53
416	446	20·30	55·24	7	4	47·35	−0·89
465	480	43·07	43·00	7	4	47·17	−0·71
501	516	37·63	38·16	7	4	46·18	+0·28
*558	581	51·04	42·05	8	3	46·97	−0·51
*558	593	51·04	24·27	8	3	46·85	−0·39
651	663	16·40	11·46	3	3	45·55	+0·91
676	697	56·14	33·57	3	3	46·60	−0·14
728	744	40·10	18·38	2	3	46·47	−0·01

Indiscriminate mean = 38° 39′ 46″·46.
Weighted mean = 38 39 46 ·46 ± 0″·09.
$e = \pm 0''{\cdot}63$.
195 observations, 31 pairs.
[Reduction to geodetic station − 0″·31.

II. WESTERN OR COAST RANGE SERIES—continued.

(97) *Latitude at Washington Square, San Francisco, California.* W. Eimbeck. Meridian telescope No. 1. July 1, 1873. One division of level = 6″·42. (This level temporarily used on this instrument.) One turn of micrometer = 64″·37.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
4 980	4 991	27·09	38·54	1	0·5	37 47 53·72	+3·25
5 067	5 116	34·40	07·39	1	0·5	55·96	+1·01
5 273	5 313	55·50	26·61	1	0·5	58·20	−1·23
5 348	5 392	42·36	13·06	1	0·5	59·33	−2·36
5 417	5 484	56·87	10·07	1	0·5	57·65	−0·68

Indiscriminate mean = 37° 47′ 56″·97.
Weighted mean = 37 47 56 ·97 ± 0″·66.
Probable error of a single result from a single pair = ± 1″·48.
5 observations, 5 pairs.
[Reduction to geodetic station 0″·00.]

(98) *Latitude at Lafayette Park, San Francisco, California.* G. Davidson. Zenith telescope No. 1. January 6 to February 24, 1888. One division of level = 0″·912, from observations at this station. One turn of micrometer = 47″·50, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
569	587	01·96	05·86	8	17	37 47 28·61	−0·53
632	646	07·78	35·61	8	17	27·73	+0·35
707	733	02·69	55·83	8	17	28·42	−0·34
761	(381)	46·86	43·08	8	13	27·61	+0·47
827	872	45·45	06·01	8	17	28·09	−0·01
948	986	05·80	51·02	8	17	27·96	+0·12
1 023	1 035	05·10	18·49	8	17	28·02	+0·06
*1 087	1 111	52·02	50·59	8	11	28·27	−0·19
*1 087	1 133	52·02	34·97	8	11	28·24	−0·16
1 192	1 214	33·93	48·00	7	16	27·89	+0·19
1 274	1 318	15·84	50·35	8	17	27·96	+0·12
1 362	1 382	48·37	01·70	8	17	27·37	+0·71
1 398	1 452	34·90	45·44	8	15	28·28	−0·20
*1 496	†9 261	21·20	19·30	1	2	27·81	+0·27
*1 496	1 538	21·20	31·34	8	11	27·78	+0·30
1 554	1 572	08·21	01·73	8	17	27·87	+0·21
1 625	1 642	09·98	56·98	8	15	28·56	−0·48
*1 705	1 726	33·85	24·08	9	12	27·91	+0·17
*1 705	1 734	33·85	25·90	9	12	27·99	+0·09
1 777	1 852	50·30	40·08	9	18	27·82	+0·26
1 867	*1 887	40·83	23·00	6	10	27·45	+0·63
1 876	*1 887	44·22	23·00	8	11	27·70	+0·38
1 928	1 952	13·49	39·67	8	17	28·05	+0·03

† Number in LaLande.

II. WESTERN OR COAST RANGE SERIES—continued.

(98) *Latitude at Lafayette Park, San Francisco, California, etc.*—Completed.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
1 989	2 020	41·49	53·14	8	17	37 47 28·60	−0·52
2 090	2 107	04·29	58·49	8	17	27·01	+1·07
2 143	2 230	55·85	32·40	8	17	28·01	+0·07
2 249	2 265	45·28	07·19	8	9	27·95	+0·13
2 300	2 313	32·05	44·31	8	17	28·68	−0·60
2 330	2 376	28·71	44·89	8	17	28·00	+0·08
(1 280)	2 493	22·09	22·40	8	17	28·13	−0·05
2 558	2 616	02·89	07·97	9	18	28·31	−0·23
2 650	2 744	02·13	54·31	9	18	28·42	−0·34
2 776	2 816	31·22	07·40	11	18	28·58	−0·50
2 842	2 897	26·83	21·98	12	19	28·21	−0·13
2 942	2 982	05·27	10·77	9	18	28·13	−0·05
3 033	3 059	33·69	28·00	11	18	28·26	−0·18
3 069	*3 150	25·06	00·34	6	10	28·47	−0·39
3 088	*3 150	32·75	00·34	10	12	28·34	−0·26

Indiscriminate mean = 37° 47′ 28″·07.
Weighted mean = 37 47 28 ·08 ± 0″·04.
$e = \pm 0''·37$.
310 observations, 38 pairs.
[Reduction to geodetic station 0″·00.]

Station No. 98. San Francisco, Lafayette Park Observatory, California. George Davidson, observer. May, 1891, to August, 1892. Instruments, zenith telescopes Nos. 1 and 3. This is one of the latitude variation stations; the results are published in detail in Coast and Geodetic Survey Report for 1893, part 2, Appendix No. 11, pp. 441–509. The number of individual observations and results for latitude at this station is not less than 6 768. The value $\varphi = 37° 47' 28''·33$ as given on page 504 is adopted.

(99) *Latitude at San Francisco, California, Presidio, old station.* G. Davidson and J. Rockwell. Zenith telescope No. 3. January 28 to February 10, 1852. One division of level = 1″·04. One turn of micrometer = 46″·63.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
808	816	52·78	46·15	2	5	37 47 35·26	+0·72
904	967	54·76	26·50	5	8	36·36	−0·38
983	*1 017	13·78	22·08	5	5	35·60	+0·38
993	*1 017	11·20	22·08	5	5	35·21	+0·77
1 034	1 065	23·74	55·32	4	7	36·59	−0·61
1 040	1 059	37·72	29·28	5	8	36·24	−0·26
1 092	1 127	48·63	09·63	4	7	35·76	+0·22
1 105	*1 132	32·25	49·84	5	5	36·56	−0·58
*1 132	1 139	49·84	37·01	6	6	36·85	−0·87

II. WESTERN OR COAST RANGE SERIES—continued.

(99) *Latitude at San Francisco, California, Presidio, old station, etc.*—Continued.

Pairs of stairs.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		″	″			° ′ ″	″
1 144	1 174	16·32	57·51	4	7	37 47 35·46	+0·52
1 192	1 214	18·79	19·23	5	8	35·43	+0·55
1 203	1 275	05·35	52·59	4	7	34·21	+1·77
1 237	1 272	43·10	35·44	5	8	35·76	+0·22
1 305	1 349	41·21	00·08	5	8	35·90	+0·08
1 313	1 328	23·66	02·80	5	8	35·52	+0·46
1 362	1 382	58·32	01·51	5	8	35·63	+0·35
1 371	1 425	30·96	16·78	5	8	35·87	+0·11
1 434	1 470	26·56	16·91	5	8	36·14	−0·16
1 445	1 475	19·76	36·84	5	8	36·49	−0·51
1 490	*1 534	47·00	05·87	4	5	36·02	−0·04
1 492	*1 534	07·65	05·87	5	5	35·86	+0·12
*1 526	1 546	58·38	29·18	5	5	36·57	−0·59
*1 526	1 547	58·38	30·00	5	5	36·38	−0·40
1 554	1 572	18·67	06·87	5	8	36·60	−0·62
1 602	1 663	46·72	29·84	5	8	36·39	−0·41
1 609	1 649	31·84	07·65	5	8	35·44	+0·54
1 705	1 726	27·16	14·65	5	8	35·84	+0·14
*1 777	1 852	18·12	31·64	5	5	35·50	+0·48
*1 777	1 862	18·12	13·18	4	5	35·33	+0·65
1 778	1 804	28·08	41·93	5	8	35·35	+0·63
1 821	1 849	25·20	10·45	5	8	35·54	+0·44
1 887	1 939	54·73	47·54	5	8	35·54	+0·44
1 900	1 942	11·72	35·56	5	8	35·84	+0·14
1 970	2 024	26·46	14·92	5	8	36·55	−0·57
1 989	*2 020	24·94	21·25	6	4	36·87	−0·89
2 005	*2 020	33·75	21·25	5	4	36·54	−0·56
2 009	*2 020	57·68	21·25	6	4	36·07	−0·09
2 090	2 107	56·96	44·37	6	8	35·77	+0·21
*2 111	2 175	51·66	49·88	5	4	36·64	−0·66
*2 111	2 187	51·66	58·08	6	4	36·11	−0·13
*2 111	2 220	51·66	00·01	6	4	36·33	−0·35
*2 143	2 199	27·50	38·03	5	5	35·94	+0·04
*2 143	2 255	27·50	19·82	6	6	36·14	−0·16
2 261	2 340	10·81	02·17	5	8	35·04	+0·94
*2 330	2 369	15·56	58·72	5	5	36·32	−0·34
*2 330	*2 376	15·56	11·62	6	4	35·81	+0·17
*2 376	2 486	11·62	33·79	5	5	35·69	+0·29
2 451	2 527	10·97	53·33	6	8	36·34	−0·36
2 501	2 519	09·20	35·01	1	3	35·28	+0·70

II. WESTERN OR COAST RANGE SERIES—continued.

(99) *Latitude at San Francisco, California, Presidio, old station, etc.*—Completed.

Pairs of stairs.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
2 532	2 551	17 ·94	06 ·40	5	8	37 47 35 ·19	+0 ·79
2 558	2 616	00 ·02	44 ·98	5	8	36 ·12	−0 ·14
2 648	2 720	30 ·62	56 ·39	5	8	35 ·82	+0 ·16
2 664	2 704	26 ·80	27 ·10	6	8	36 ·43	−0 ·45
2 731	*2 776	10 ·50	04 ·14	4	5	36 ·83	−0 ·85
*2 776	2 816	04 ·14	11 ·54	5	5	35 ·88	+0 ·10
2 732	2 799	35 ·43	47 ·30	5	8	36 ·64	−0 ·66
2 867	*2 884	10 ·52	39 ·11	5	5	36 ·23	−0 ·25
*2 884	2 958	39 ·11	09 ·74	5	5	35 ·91	+0 ·07
2 876	2 897	25 ·54	01 ·43	5	8	36 ·28	−0 ·30
2 942	2 982	31 ·54	20 ·87	5	8	35 ·92	+0 ·06
2 989	3 016	35 ·84	49 ·30	5	8	36 ·30	−0 ·32
2 999	3 059	30 ·08	05 ·29	5	8	36 ·96	−0 ·98
3 135	3 171	56 ·62	12 ·56	5	8	35 ·57	+0 ·41
3 169	3 246	07 ·94	56 ·40	5	8	35 ·41	+0 ·57
3 221	3 250	42 ·73	51 ·16	5	8	35 ·80	+0 ·18
3 255	3 341	43 ·32	32 ·39	5	8	36 ·95	−0 ·97
3 292	3 358	14 ·82	50 ·27	5	8	36 ·33	−0 ·35
3 390	3 453	49 ·13	03 ·82	5	8	36 ·47	−0 ·49

Indiscriminate mean = 37° 47′ 35″·99.
Weighted mean = 37 47 35 ·98 ± 0″·04.
$e = \pm 0''\cdot 47$.
336 observations, 68 pairs.
[Reduction to geodetic station — 0″·24.]

II. WESTERN OR COAST RANGE SERIES—continued.

(100) *Latitude at San Francisco, Presidio new station, California.* O. B. French. Zenith telescope No. 3. November 5–13, 1896. One division of level $= \left\{ \begin{matrix} 0''.808 \text{ upper} \\ 0 .855 \text{ lower} \end{matrix} \right\}$, determined at this station. One turn of micrometer = 47''.636, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n'	w	Latitude.	v
		"	"			° ' "	"
991	998	51 .36	00 .38	6	14	37 47 48 .37	−0 .15
1 045	*1 065	48 .10	28 .81	5	9	49 .18	−0 .96
1 053	*1 065	56 .74	28 .81	6	10	48 .82	−0 .60
1 087	1 111	11 .63	14 .33	6	14	48 .61	−0 .39
1 138	(586)	29 .51	30 .21	6	14	48 .00	+0 .22
(600)	1 203	05 .25	58 .92	6	14	47 .89	+0 .33
1 262	1 287	50 .96	18 .98	6	14	48 .22	0 .00
1 302	1 313	35 .15	43 .75	6	14	48 .00	+0 .22
1 363	1 382	17 .35	56 .25	6	14	48 .34	−0 .12
1 425	1 449	40 .98	34 .16	5	14	48 .12	+0 .10
1 496	1 538	31 .85	45 .13	5	14	48 .14	+0 .08
1 554	1 572	27 .11	21 .45	6	14	48 .11	+0 .11
1 602	1 663	20 .64	44 .12	5	14	48 .19	+0 .03
1 705	1 726	10 .08	00 .33	6	14	48 .16	+0 .06
1 749*p*	1 751	08 .77	33 .54	6	14	48 .18	+0 .04
1 821	1 849	07 .14	08 .62	6	14	47 .62	+0 .60
1 867	*1 887	31 .49	17 .20	6	10	47 .81	+0 .41
1 876	*1 887	36 .56	17 .20	5	9	47 .94	+0 .28
1 928	1 952	11 .09	41 .41	6	14	47 .90	+0 .32
1 989	*2 020	45 .71	01 .82	6	10	48 .99	−0 .77
2 009	*2 020	29 .90	01 .82	5	9	49 .00	−0 .78
2 090	2 107	20 .19	16 .49	6	14	47 .91	+0 .31
2 143	2 230	16 .99	03 .39	6	14	48 .47	−0 .25
2 249	2 265	18 .58	42 .40	6	8	47 .96	+0 .26
2 300	2 313	13 .56	25 .98	5	14	48 .05	+0 .17
2 330	*2 369	12 .66	17 .59	6	10	48 .22	0 .00
2 362	*2 369	53 .25	17 .59	6	10	48 .58	−0 .36

Indiscriminate mean = 37° 47′ 48″.25.
Weighted mean = 37 47 48 .22 ± 0″.05.
$e = \pm 0''.22$.

155 observations. 27 pairs.

[Reduction to geodetic station 0″.00.]

II. WESTERN OR COAST RANGE SERIES—continued.

(101) *Latitude at Tamalpais, California.* J. F. Pratt. Zenith telescope No. 1. September 12–26, 1882. One division of level = 0″·91, determined at this station. One turn of micrometer = 47″·480, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 901	6 924	47·23	58·25	6	5	37 55 19·72	−0·64
6 944	6 985	22·23	48·68	7	5	18·42	+0·66
7 022	7 073	13·52	18·75	6	5	18·91	+0·17
[1 819]	7 143	30·99	50·06	6	5	18·62	+0·46
7 173	7 220	52·72	09·55	7	5	18·34	+0·74
7 262	7 275	05·86	47·56	7	5	18·87	+0·21
7 320	7 385	30·84	28·04	6	5	20·06	−0·98
7 410	7 468	57·48	49·10	6	5	20·24	−1·16
7 505	7 566	40·57	22·48	6	5	19·32	−0·24
7 585	7 637	40·68	30·81	7	5	19·51	−0·43
7 693	7 727	31·91	36·69	7	5	19·67	−0·59
7 742	7 759	26·63	27·66	6	5	18·41	+0·67
7 845	7 914	49·31	28·96	7	5	18·97	+0·11
7 958	(3 854)	16·46	42·85	7	5	18·82	+0·26
8 032	8 059	25·63	48·65	7	5	18·38	+0·70
8 097	8 114	42·70	46·12	7	5	18·59	+0·49
8 125	(3 950)	19·51	04·35	7	5	18·21	+0·87
8 212	(3 981)	50·66	02·51	7	5	19·33	−0·25
8 296	8 322	06·56	02·71	7	5	19·00	+0·08
8 374	7	46·89	17·22	7	5	18·08	+1·00
*52	*52	24·63	24·63	7	3	19·11	−0·03
(51)	78	36·36	21·53	7	5	19·31	−0·23
92	133	43·70	02·72	7	5	20·25	−1·17
164	197	45·15	58·08	7	5	18·88	+0·20
223	255	48·61	34·89	7	5	18·45	+0·63
283	334	21·77	19·45	7	5	20·20	−1·12
345	404	11·65	24·16	7	5	19·69	−0·61
441	514	07·19	01·49	7	5	18·83	+0·25

Indiscriminate mean = 37° 55′ 19″·08.
Weighted mean = 37 55 19 ·08 ± 0″·08.
$e = \pm 0''{\cdot}56$.
189 observations, 28 pairs.
[Reduction to geodetic station = 0″·04.]

II. WESTERN OR COAST RANGE SERIES—continued.

(102) *Latitude at Mount Helena, California.* W. Eimbeck. Zenith telescope No. 1. November 7–20, 1876. One division of level = 0″·933, determined at San Francisco March, 1877. One turn of micrometer = 45″·795, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
7 943	7 967	46 ·13	05 ·55	5	8	38 40 00 ·76	+0 ·29
8 003	8 039	00 ·38	32 ·52	6	9	01 ·03	+0 ·02
8 074	8 105	57 ·92	42 ·03	5	8	00 ·31	+0 ·74
8 159	8 225	45 ·69	49 ·22	5	8	00 ·94	+0 ·11
8 248	8 279	09 ·26	28 ·83	5	8	00 ·88	+0 ·17
8 307	8 350	01 ·62	27 ·73	6	9	01 ·55	−0 ·50
8 372	32	17 ·15	58 ·49	4	8	01 ·47	−0 ·42
116	126	50 ·90	10 ·56	4	8	01 ·22	−0 ·17
153	178	09 ·04	04 ·22	6	9	01 ·34	−0 ·29
214	244	57 ·93	57 ·32	5	8	00 ·57	+0 ·48
264	314	08 ·37	20 ·05	6	9	01 ·57	−0 ·52
334	377	14 ·60	54 ·10	6	5	02 ·09	−1 ·04
416	446	35 ·78	10 ·05	6	9	01 ·06	−0 ·01
465	480	57 ·51	55 ·67	5	8	00 ·88	+0 ·17
501	516	50 ·71	51 ·44	6	7	02 ·10	−1 ·05
*558	581	03 ·16	53 ·32	6	6	00 ·60	+0 ·45
*558	593	03 ·16	34 ·69	6	6	00 ·66	+0 ·39
676	697	04 ·45	40 ·06	6	9	00 ·54	+0 ·51
728	744	46 ·65	24 ·29	4	8	01 ·68	−0 ·63
777	794	34 ·14	55 ·73	5	8	00 ·88	+0 ·17
827	861	51 ·24	09 ·20	5	8	00 ·25	+0 ·80
920	948	46 ·40	59 ·15	6	7	00 ·85	+0 ·20
989	995	43 ·74	27 ·11	5	8	01 ·08	−0 ·03

Indiscriminate mean = 38° 40′ 01″·06.
Weighted mean = 38 40 01 ·05 ± 0″·07.
$e = \pm 0''\cdot 42$.
123 observations, 23 pairs.
[Reduction to geodetic station + 0″·95.]

II. WESTERN OR COAST RANGE SERIES—continued.

(103) *Latitude at Ross Mountain, California.* A. T. Mosman. Zenith telescope No. 3. December 27, 1859, to January 28, 1860. One division of level = 1″·10. One turn of micrometer = 46″·64, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
1 006	1 017	34·37	32·78	7	9	38 30 10·06	−0·06
*1 025	1 035	43·00	28·90	7	6	09·18	+0·82
*1 025	1 059	43·00	45·50	6	6	09·75	+0·25
1 083	1 097	16·85	15·63	7	9	10·03	−0·03
1 138	1 142	30·80	39·87	7	9	10·70	−0·70
1 219	1 268	54·45	37·99	8	9	10·89	−0·89
1 323	1 364	23·46	50·94	6	8	09·11	+0·89
1 444	*1 477	35·77	21·14	8	6	09·83	+0·17
1 462	*1 477	00·57	21·14	8	6	09·45	+0·55
1 530	1 534	33·25	18·20	8	9	09·59	+0·41
1 546	*1 568	43·40	47·75	7	6	09·92	+0·08
1 547	*1 568	43·37	47·75	7	6	09·66	+0·34
1 613	1 668	57·10	37·71	8	9	10·14	−0·14
1 676	1 737	21·82	47·30	6	8	09·51	+0·49
1 767	*1 797	46·32	53·67	7	6	09·64	+0·36
*1 797	1 835	53·67	01·66	7	6	09·42	+0·58
1 851	1 874	32·54	24·08	7	9	10·04	−0·04
1 888	1 925	18·85	24·39	8	9	09·97	+0·03
1 932	1 942	30·32	33·74	7	9	10·14	−0·14
1 953	1 992	41·32	44·14	9	10	09·48	+0·52
*2 024	2 028	23·08	45·00	7	5	09·85	+0·15
*2 024	2 063	23·08	06·53	8	5	09·94	+0·06
*2 024	2 064	23·08	56·67	7	5	11·14	−1·14
2 084	*2 114	23·95	33·34	9	6	10·27	−0·27
2 090	*2 114	11·54	33·34	9	6	10·66	−0·66
2 173	2 192	01·50	28·23	8	9	10·44	−0·44
2 209	2 216	22·22	52·98	9	10	09·41	+0·59
2 239	*2 270	29·75	35·40	9	6	10·59	−0·59
2 241	*2 270	40·96	35·40	9	6	10·13	−0·13
2 280	*2 312	14·36	35·59	8	6	09·46	+0·54
2 285	*2 312	50·91	35·59	9	6	10·10	−0·10
2 341	2 364	38·64	32·38	8	9	10·51	−0·51
2 397	2 398	40·20	38·20	8	9	09·61	+0·39
2 459	2 493	35·40	48·00	8	9	09·81	+0·19
*2 540	2 606	52·43	22·50	9	6	09·87	+0·13
*2 540	2 609	52·43	36·32	9	6	09·61	+0·39
577	658	40·62	03·87	9	10	10·51	−0·51
676	698	38·71	08·20	9	10	10·89	−0·89
766	806	14·57	08·76	9	10	10·38	−0·38

II. WESTERN OR COAST RANGE SERIES—continued.

(103) *Latitude at Ross Mountain, California, etc.*—Completed.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
*866	875	54 ·38	52 ·85	10	7	38 30 09 ·54	+0 ·46
*866	885	54 ·38	49 ·40	10	7	10 ·43	−0 ·43
921	948	19 ·17	51 ·44	10	10	09 ·98	+0 ·02
989	995	25 ·21	07 ·06	10	10	09 ·47	+0 ·53
1 025	1 024	43 ·00	08 ·50	10	10	09 ·29	+0 ·71
1 058	1 096	06 ·00	45 ·00	10	10	10 ·78	−0 ·78
1 119	1 204	19 ·45	21 ·12	10	10	10 ·40	−0 ·40
1 254	*1 262	59 ·00	50 ·80	10	7	09 ·26	+0 ·74
*1 262	1 301	50 ·80	11 ·89	10	7	09 ·54	+0 ·46
1 313	1 350	09 ·55	11 ·69	8	9	10 ·03	−0 ·03
1 424	1 453	27 ·34	48 ·66	8	9	10 ·22	−0 ·22
1 460	1 474	05 ·00	04 ·82	9	10	10 ·16	−0 ·16
*1 501	1 551	21 ·08	49 ·17	8	6	10 ·16	−0 ·16
*1 501	1 571	21 ·08	03 ·43	8	6	10 ·09	−0 ·09

Indiscriminate mean = 38° 30′ 09″·98.
Weighted mean = 38 30 10 ·00 ± 0″·04.
$e = \pm 0''{\cdot}52$.
437 observations, 53 pairs.
[Reduction to geodetic station 0″·00.]

(104) *Latitude at Sulphur, California.* G. Davidson. Zenith telescope No. 3. September 8–28, 1859. One division of level = 1″·10. One turn of micrometer = 46″·540, from circumpolar observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 073	*6 091	29 ·38	34 ·99	5	8	38 45 45 ·11	−0 ·54
*6 091	6 151	34 ·99	14 ·29	2	4	43 ·55	+1 ·02
6 185	6 241	15 ·27	01 ·11	8	15	44 ·25	+0 ·32
6 268	6 365	02 ·70	42 ·25	11	17	44 ·77	−0 ·20
6 387	6 477	08 ·39	29 ·87	7	14	44 ·57	0 ·00
6 601	6 678	13 ·71	30 ·00	7	14	44 ·41	+0 ·16
6 640	6 652	13 ·85	13 ·04	6	13	43 ·67	+0 ·90
*6 690	6 730	01 ·99	33 ·80	3	6	44 ·48	+0 ·09
*6 690	6 734	01 ·99	14 ·20	4	7	44 ·03	+0 ·54
6 740	6 799	09 ·66	21 ·94	12	18	44 ·21	+0 ·36
6 861	6 868	58 ·05	59 ·72	7	14	44 ·15	+0 ·42
6 918	6 944	49 ·56	23 ·20	7	14	45 ·07	−0 ·50
6 963	6 998	49 ·07	21 ·77	7	14	44 ·08	+0 ·49
7 084	7 101	14 ·20	24 ·24	11	17	45 ·16	−0 ·59
7 112	7 131	19 ·10	04 ·62	7	14	44 ·72	−0 ·15
7 164	7 233	32 ·16	26 ·48	7	14	44 ·62	−0 ·05

II. WESTERN OR COAST RANGE SERIES—continued.

(104) *Latitude at Sulphur, California, etc.*—Completed.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
7 256	7 278	35·90	41·79	12	18	38 45 44·45	+0·12
7 297	7 336	52·73	30·17	12	18	44·57	0·00
7 361	7 401	37·56	35·01	7	14	44·94	−0·37
7 465	7 480	23·75	47·62	6	13	44·90	−0·33
7 494	7 520	13·89	51·35	6	13	44·50	+0·07
7 528	7 582	07·85	55·95	6	13	44·97	−0·40
7 621	7 641	44·53	29·50	5	12	45·29	−0·72
7 654	7 689	52·63	43·77	5	12	44·37	+0·20
7 707	7 742	05·62	09·22	5	12	44·26	+0·31
7 796	7 810	13·45	18·73	9	16	44·27	+0·30
7 833	7 876	22·70	56·85	9	16	44·38	+0·19
7 901	7 915	57·44	35·92	8	15	44·72	−0·15
7 953	7 997	35·18	10·59	9	16	45·01	−0·44
8 003	8 039	24·90	01·27	9	16	44·81	−0·24
8 125	8 133	51·50	14·10	8	15	44·10	+0·47
8 156	8 261	36·53	44·47	8	15	44·03	+0·54
8 159	8 224	20·72	19·78	8	15	44·90	−0·33
6 456	6 493	07·36	45·16	7	14	44·49	+0·08
6 520	6 571	47·32	58·24	10	17	44·53	+0·04
*6 623	6 674	25·49	04·41	8	10	44·44	+0·13
*6 623	6 676	25·49	09·87	3	6	45·51	−0·94
6 698	6 728	41·10	28·50	7	14	44·21	+0·36
6 863	6 901	15·92	37·88	7	14	45·02	−0·45
6 943	6 959	32·27	33·50	6	13	44·90	−0·33
7 001	7 008	08·50	22·78	6	13	44·84	−0·27
7 144	7 222	07·25	23·81	7	14	44·50	+0·07
7 363	7 405	58·66	27·34	7	14	44·86	−0·29
7 444	7 489	49·07	04·36	6	13	44·53	+0·04
7 519	7 597	46·56	33·30	6	13	44·62	−0·05
7 627	7 676	12·34	47·55	6	13	44·59	−0·02
*7 712	7 778	56·14	30·50	6	9	44·08	+0·49
*7 712	7 782	56·14	56·02	6	9	44·24	+0·33

Indiscriminate mean $= 38° \ 45′ \ 44″ {\cdot} 56$.
Weighted mean $= 38 \ \ 45 \ \ 44 \ \ 57 \pm 0″{\cdot}04$.
$e = \pm 0″{\cdot}50$.
341 observations, 48 pairs.
[Reduction to geodetic station 0″·00.]

II. WESTERN OR COAST RANGE SERIES—continued.

(105) *Latitude at Ukiah, California.* C. H. Sinclair. Meridian telescope No. 1. November 10-14, 1897. One division of level = 1″·901, determined at office April, 1893. One turn of micrometer = 66″·073, determined from the latitude observations at this station.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
*7 746	7 757	08 ·17	07 ·17	4	12	39 08 54 ·85	−0 ·45
*7 746	7 798	08 ·17	18 ·46	4	12	54 ·42	−0 ·02
7 807P	7 848	20 ·50	43 ·66	4	19	54 ·27	+0 ·13
7 858	7 880	00 ·56	56 ·19	5	19	53 ·87	+0 ·53
7 901	7 915	09 ·30	45 ·36	5	21	54 ·83	−0 ·43
7 945	7 961	35 ·19	36 ·93	5	21	54 ·29	+0 ·11
7 972	(3 843)	06 ·95	53 ·12	5	20	54 ·62	−0 ·22
8 031	8 074	04 ·97	09 ·95	5	21	54 ·55	−0 ·15
8 104	8 127	49 ·53	50 ·90	5	21	54 ·50	−0 ·10
8 195	8 212	46 ·88	53 ·66	5	21	53 ·83	+0 ·57
(3 970)	8 224	57 ·53	00 ·02	5	19	54 ·10	+0 ·30
8 231	8 284	55 ·51	51 ·90	5	21	54 ·54	−0 ·14
8 344	8	02 ·96	38 ·32	5	21	54 ·35	+0 ·05
16	(25)	04 ·12	58 ·97	5	19	54 ·73	−0 ·33
51	(43)	30 ·23	17 ·54	3	13	54 ·28	+0 ·12
102	126	28 ·25	12 ·31	5	21	54 ·91	−0 ·51
(88)	*201	06 ·62	32 ·55	5	11	53 ·90	+0 ·50
*201	215	32 ·55	35 ·53	5	14	54 ·25	+0 ·15

Indiscriminate mean = 39° 08′ 54″·39.
Weighted mean = 39 08 54 ·40 ± 0″·05.
$e = \pm 0''\cdot34$.
85 observations, 18 pairs.
[Reduction to court-house + 3″·42.]

II. WESTERN OR COAST RANGE SERIES—continued.

(106) *Latitude at Point Reyes, California.* G. Davidson. Zenith telescope No. 3. February 6–8, 1853. One division of level = 2″·60. One turn of micrometer = 46″·63.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
2 084	2 107	15·10	46·42	1	0·7	37 59 33·52	+0·10
*2 163	2 175	47·73	52·28	1	0·3	33·14	+0·48
*2 163	2 187	47·73	00·60	1	0·3	33·04	+0·58
*2 163	2 220	47·73	03·55	1	0·3	34·27	−0·65
2 294	*2 330	16·80	20·81	1	0·4	34·63	−1·01
*2 330	2 349	20·81	27·90	1	0·4	33·96	−0·34
*2 407	2 423	51·77	59·09	3	1·3	33·18	+0·44
*2 407	2 457	51·77	10·59	3	1·3	32·55	+1·07
2 486	2 495	41·11	42·22	1	0·7	34·14	−0·52
2 555	2 606	23·20	20·40	1	0·7	34·22	−0·60
2 683	2 732	44·49	45·40	2	1·3	34·02	−0·40
2 776	2 810	14·80	32·00	1	0·7	32·81	+0·81
2 842	*2 867	34·47	21·68	2	0·9	35·88	−2·26
*2 867	2 876	21·68	37·36	2	0·9	32·69	+0·93
3 026	3 075	54·00	57·16	1	0·7	32·66	+0·96
*3 129	3 135	22·89	11·46	1	0·4	34·24	−0·62
*3 129	3 172	22·89	54·14	1	0·4	33·78	−0·16

Indiscriminate mean = 37° 59′ 33″·69.
Weighted mean = 37 59 33 ·62 ± 0″·13.
$e = \pm 1''\cdot 24$.
24 observations, 17 pairs.
[Reduction to geodetic station 0″·00.]

(107) *Latitude at Bodega, California.* G. Davidson. Zenith telescope No. 3. July 9, 1853. One division of level = 2″·60. One turn of micrometer = 46″·63.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 475	6 480	43·00	03·90	1	2	38 18 18·31	+1·90
6 581	6 599	15·80	32·10	1	2	20·64	−0·43
6 657	6 687	56·06	38·50	1	2	20·72	−0·51
6 730	*6 762	20·95	46·20	1	1	19·95	+0·26
6 734	*6 762	02·50	46·20	1	1	19·24	+0·97
6 806	6 849	27·25	04·90	1	2	19·76	+0·45
6 813	6 860	10·95	05·03	1	2	22·23	−2·02
6 937	*6 996	26·30	26·60	1	1	19·78	+0·43
6 967	*6 996	29·00	26·60	1	1	20·72	−0·51
7 027	7 073	31·00	59·22	1	2	19·48	+0·73
7 149	7 220	13·27	52·25	1	2	21·24	−1·03
7 246	7 294	02·30	26·77	1	2	19·88	+0·33

Indiscriminate mean = 38° 18′ 20″·16.
Weighted mean = 38 18 20 ·21 ± 0″·21.
Probable error of result from a single pair = ± 0″·69.
12 observations, 12 pairs.
[Reduction to geodetic station 0″·00.]

II. WESTERN OR COAST RANGE SERIES—completed.

(108) *Latitude at Mendocino City, California.* G. Davidson. Zenith telescope No. 3. July 11, 1853. One division of level = 1″·04. One turn of micrometer = 46″·63.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
6 087	6 129	44·20	26·00	1	4	39 18 06·32	−0·76
6 185	6 223	23·55	42·01	1	4	04·77	+0·79
6 322	*6 368	22·20	18·50	1	3	06·89	−1·33
6 341	*6 368	36·80	18·50	1	3	06·07	−0·51
6 392	6 404	45·34	49·39	1	4	04·04	+1·52
6 438	6 477	48·32	56·71	1	4	05·03	+0·53
6 497	6 520	24·64	16·76	1	4	05·57	−0·01
6 547	6 566	57·58	15·80	1	4	04·78	+0·78
6 589	6 601	57·30	50·59	1	4	06·09	−0·53
6 690	*6 723	45·80	35·53	1	3	05·80	−0·24
6 691	*6 723	27·06	35·53	1	3	05·33	+0·23
6 765	6 817	33·10	19·00	1	4	05·25	+0·31
6 866	6 924	45·82	57·97	1	4	06·60	−1·04
6 959	6 973	37·30	02·41	1	4	05·83	−0·27
6 997	*7 041	27·90	26·34	1	3	06·03	−0·47
7 006	*7 041	40·27	26·34	1	3	05·22	+0·34
7 126	7 153	48·88	20·54	1	4	05·33	+0·23

Indiscriminate mean = 39° 18′ 05″·58.
Weighted mean = 39 18 05 ·56 ± 0″·12.
Probable error of result from a single pair = ±0″·49.
17 observations, 17 pairs.
[Reduction to geodetic station 0″·00.]

(109) *Latitude at Point Arena, California.* G. Davidson. Meridian telescope No. 1. May 26, 1870. One division of level = 1″·00. One turn of micrometer = 65″·38.

Pairs of stars.		Adopted seconds of mean N. P. D.		n′	w	Latitude.	v
		″	″			° ′ ″	″
5 847	5 874	15·21	45·76	1	3	38 55 09·53	+0·81
5 940	5 972	24·47	57·44	1	3	09·67	+0·67
6 084	6 129	11·50	26·66	1	3	10·91	−0·57
6 185	6 241	05·75	44·41	1	3	09·24	+1·10
6 357	6 365	43·49	08·75	1	3	09·64	+0·70
6 395	6 453	30·00	04·47	1	3	11·78	−1·44
6 520	6 571	54·12	55·07	1	3	11·02	−0·68
6 586	6 615	20·78	47·44	1	3	10·72	−0·38
6 637	6 687	06·71	36·80	1	3	11·34	−1·00
6 714	6 741	17·55	56·85	1	3	09·54	+0·80

Indiscriminate mean = 38° 55′ 10″·34.
Weighted mean = 38 55 10 ·34 ± 0″·19.
Probable error of result from a single pair = ±0″·61.
10 observations, 10 pairs.
[Reduction to geodetic station 0″·00.]

F. REDUCTION OF THE OBSERVED LATITUDES TO THE SEA LEVEL.

In consequence of the earth's rotation, the vertical line at a place is slightly curved and is concave to the pole. The observed latitude being the angle which the tangent to this curve makes with the plane of the equator, needs, therefore, to be referred to the foot point at the sea level. This correction is always negative, and is given by *—

$$i = 0{\cdot}000\,171 h \sin 2\varphi$$

where h = elevation of station in metres, φ = the latitude, and i = the curvature correction in seconds. For latitude 39° we have $i = 0{\cdot}000\,167h$ very nearly. This correction reaches up to $0''{\cdot}7$ for our highest stations, and is therefore many times greater than the probable error assigned to the resulting latitude and can not be neglected.

G. CORRECTIONS TO OBSERVED LATITUDES, AZIMUTHS, AND LONGITUDES FOR VARIATION OF POLE OF ROTATION.

When the change of latitude is compared with the probable error of observation resulting from accurate measures, it is seen that the effect of the systematic variation in the position of the pole of rotation as determined by Dr. Seth C. Chandler may be several times larger than the mere observing error. Hence the correction for variation of pole can not be ignored in any refined deductions from latitude observations. A similar remark applies also to the corrections to azimuths, with this difference, however, that here the probable *observing* error generally exceeds the effect due to change of pole, thus rendering the correction for shift of pole of less consequence. The correction to differences of longitude due to the same cause is quite small, and may generally be neglected as covered by the error of observation.

Dr. Chandler's latest expressions are contained in No. 446 of Gould's Astronomical Journal, October, 1898.† His coordinates x and y of the average or normal position of the pole with reference to the position of the instantaneous pole of rotation are given by—

$$\begin{aligned} x &= r_1 \sin (t - T_1)\, \theta + 0''{\cdot}095 \sin (\odot - 308^\circ) \\ y &= r_1 \cos (t - T_1)\, \theta + 0\ {\cdot}110 \cos (\odot - 3^\circ) \\ \text{where } T_1 &= 2\,412\,646 + 427{\cdot}0\, E - 0{\cdot}08\, E^2 \\ \theta &= 0^\circ{\cdot}843 + 0{\cdot}000\,316\, E \\ \text{and } r_1 &= 0''{\cdot}125 + 0''{\cdot}05 \sin (2\,414\,363 - t) \times 0''{\cdot}015 \end{aligned}$$

Here t and T_1 are expressed in Julian dates; t is the epoch of observation, E is the period, and $\odot$ the sun's longitude.

The corrections for latitude, azimuth, and longitude are given by the expressions—

$$\begin{aligned} \triangle\varphi &= \varphi - \varphi_0 = x \sin \lambda - y \cos \lambda \\ \triangle\alpha &= \alpha - \alpha_0 = (x \cos \lambda + y \sin \lambda) \sec \varphi \\ \triangle\lambda &= \lambda - \lambda_0 = -(x \cos \lambda + y \sin \lambda) \tan \varphi \end{aligned}$$

*Clarke's Geodesy (Oxford, 1880), p. 102; also Helmert's Höhere Geodäsie (Leipzig, 1884), Vol. II, p. 99.
†See also ibid. Nos. 329, November, 1894; 360, December, 1895; 392, January, 1897, and 406, June, 1897.

where φ = observed latitude, α = observed azimuth, λ = observed longitude of place counted westward from Greenwich, and φ_0, α_0, λ_0 the corresponding corrected values.

For stations occupied between the years 1890·0 and 1897·5 the coordinates x and y were taken from Dr. Albrecht's report of 1898.* For this interval a convenient table is given by him of the quantity $\varphi - \varphi_0$ for various longitudes, which can also be employed for the azimuthal correction. In this system the coordinates are those of the instantaneous pole of rotation with reference to the average position of the pole (of figure), and the corrections to latitude, azimuth, and longitude are found by-

$$\varphi - \varphi_0 = x \cos \lambda + y \sin \lambda$$
$$\alpha - \alpha_0 = (-x \sin \lambda + y \cos \lambda) \sec \varphi$$
$$\lambda - \lambda_0 = (x \sin \lambda - y \cos \lambda) \tan \varphi$$

For the interval 1890–1897½ the resulting corrections are quite reliable, as they depend directly upon observed variations, but for other years the general formulæ as given above must be made use of.

For the greater part of the stations these corrections were computed by Mr. D. L. Hazard.

H. SYNOPSIS OF RESULTS FOR LATITUDE OF STATIONS DETERMINED ASTRONOMICALLY.

No.	Name of station.	State.	Year.	Observed latitude.	Probable error.	Approximate altitude of station.	Reduction to sea level.	Correction for variation of pole.	Final seconds of latitude.
				° ′ ″	″	m.	″	″	″
1	Cape May	N. J.	1881	38 55 44·66	±0·12	10	0	+0·05	44·71
	Cape May	N. J.	1891	44·77	±0·07	10	0	−0·17	44·60
	Adopted value of astronomic station	....	....	....	±0·06	....	....	....	44·63
2	Cape Henlopen	Del.	1897	38 46 40·00	±0·05	20	0	+0·07	40·07
3	Dover	Del.	1897	39 09 13·62	±0·06	12	0	−0·15	13·47
4	Principio	Md.	1866	39 35 32·81	±0·04	30 (?)	−·01	−0·05	32·75
5	Poole Island	Md.	1847	39 17 17·52	±0·15	5	0	0·00	17·52
6	Calvert	Md.	1871	38 21 31·88	±0·11	30	−·01	−0·16	31·71
7	Taylor	Md.	1847	38 59 46·08	±0·12	30	−·01	0·00	46·07
8	Marriott	Md.	1846	38 52 24·73	±0·19	77	−·01	−0·07	24·65
	Marriott	Md.	1849	25·12	±0·06	77	−·01	−0·06	25·05
	Adopted value	....	....	....	±0·06	....	....	....	25·05
9	Webb	Md.	1850	39 05 25·21	±0·04	73	−·01	+0·15	25·35
10	Hill	Md.	1850	38 53 52·31	±0·05	85	−·01	+0·06	52·36
11	Soper.................................	Md.	1850	39 05 10·69	±0·09	144	−·02	−0·06	10·61
12	Seaton, Washington	D. C.	1850	38 53 25·20	±0·15	28	0	−0·08	25·12
13	Coast and Geodetic Survey Office, Washington, station in yard	D. C.	1891	38 53 07·51	±0·06	16	0	−0·13	07·38
	Coast and Geodetic Survey Office, Washington, station in yard	D. C.	1892	07·46	±0·06	16	0	−0·16	07·30
	Coast and Geodetic Survey Office, Washington, station in yard	D. C.	1894	07·31	±0·04	16	0	+0·05	07·36
	Adopted value		....	....	±0·02	....	....	....	07·35
14	United States Naval Observatory, old site, dome, Washington	D. C.	1861 to 1864	38 53 38·78	±0·10	30	−·01	....	....
	United States Naval Observatory, old site, dome, Washington	D. C.	1883	38·94	±0·06	30	−·01	....	....

*Bericht über den Stand der Erforschung der Breiten-Variation. Central-Bureau der Internationalen Erdmessung. Berlin, 1898.

H. SYNOPSIS OF RESULTS FOR LATITUDE OF STATIONS, ETC.—Cont'd.

No.	Name of station.	State.	Year.	Observed latitude.	Probable error.	Approximate altitude of station.	Reduction to sea level.	Correction for variation of pole.	Final seconds of latitude.
				° ′ ″	″	m.	″	″	″
	United States Naval Observatory, old site, dome, Washington	D. C.	1866 to 1888	38·70	±0·05	30	−·01	....	....
	United States Naval Observatory, old site, dome, Washington	D. C.	1893	38·80	±0·05	30	−·01	....	....
	Adopted value	....	....	38·79	±0·03	....	....	....	38·78
15	United States Naval Observatory, new site, Georgetown Heights, clock room	D. C.	1893 to 1896	38 55 13·70	±0·10	85	−·01	....	13·69
	United States Naval Observatory, new site, Georgetown Heights, clock room	D. C.	1897	13·93	±0·06	85	−·01	−0·16	13·76
	Adopted value	....	....	....	±0·06	....	....	....	13·74
16	Causten	D. C.	1851	38 55 32·18	±0·06	118	−·02	−0·14	32·02
17	Georgetown College, observatory dome	D. C.	1846	38 54 25·80	....	60	−·01	....	25·79
18	Rockville	Md.	1891 1892	39 05 10·45	±0·05	152	−·03	....	10·42
19	Sugar Loaf	Md.	1879	39 15 49·71	±0·10	390	−·07	−0·10	49·54
20	Maryland Heights	Md.	1870	39 20 32·10	±0·04	444	−·07	+0·16	32·19
21	Bull Run	Va.	1871	38 52 56·79	±0·07	420	−·07	0	56·72
22	Strasburg	Va.	1881	38 59 31·49	±0·09	200	−·03	+0·10	31·56
23	Clark Mountain	Va.	1871	38 18 39·80	±0·06	335	−·06	−0·14	39·60
24	Charlottesville, University, transit	Va.	1882	38 02 00·95	±0·14	200	−·03	+0·17	01·09
25	Long Mount	Va.	1875	37 17 28·72	±0·09	438	−·07	+0·19	28·84
26	Elliott Knob	Va.	1878	38 09 57·51	±0·11	1 363	−·23	−0·20	57·08
27	Keeney	W. Va.	1880	37 46 23·26	±0·11	1 200	−·20	+0·01	23·07
28	Charleston	W. Va.	1883	38 21 06·87	±0·10	185	−·03	+0·11	06·95
29	Piney	W. Va.	1883	38 26 41·33	±0·06	336	−·06	+0·13	41·40
30	Gould	Ohio	1885	38 38 29·96	±0·23	300 (?)	−·05	−0·13	29·78
31	Minerva	Ky.	1887	38 42 30·88	±0·05	300 (?)	−·05	+0·06	30·89
32	Cincinnati, Mount Lookout Observatory, dome	Ohio	1881	39 08 19·54	±0·08	250	−·04	+0·15	19·65
33	Reizin	Ind.	1889	39 02 53·58	±0·10	306	−·05	+0·23	53·76
34	Weed Patch	Ind.	1889	39 10 00·55	±0·06	351	−·06	+0·19	00·68
35	Vincennes	Ind.	1881	38 40 36·77	±0·06	132	−·02	+0·05	36·80
36	Parkersburg, △ station	Ill.	1879	38 34 53·20	±0·09	173	−·03	−0·12	53·05
37	Olney West Base △ station	Ill.	1880	38 51 41·23	±0·06	151	−·03	+0·08	41·28
38	Newton	Ill.	1883	38 55 30·87	±0·07	167	−·03	+0·26	31·10
39	Bording	Ill.	1882	38 36 50·73	±0·06	165	−·03	+0·23	50·93
40	St. Louis, Washington University	Mo.	1869 1870	38 38 02·77	±0·13	155	−·03	+0·03	02·77
	St. Louis, Washington University	Mo.	1881	02·81	±0·09	155	−·03	+0·11	02·89
	Adopted value referred to Second Presbyterian Church	....	....	00·54	±0·07	....	....	....	00·59
41	Jefferson	Mo.	1879	38 33 43·99	±0·07	169	−·03	−0·01	43·95
42	Hunter	Mo.	1880	38 25 48·01	±0·10	200 (?)	−·03	+0·02	48·00
43	Kansas City	Mo.	1882	39 05 50·92	±0·09	232	−·04	+0·24	51·12
44	Adams	Kans.	1888	39 02 41·72	±0·10	320 (?)	−·06	+0·14	41·80
45	Salina West Base	Kans.	1896	38 51 03·57	±0·18	372	−·06	+0·01	03·52
46	Ellsworth	Kans.	1885	38 43 47·60	±0·13	470	−·08	−0·03	47·49
47	Russell Southeast	Kans.	1893	38 51 22·90	±0·06	559	−·09	−0·08	22·73
48	Wallace	Kans.	1885	38 54 44·38	±0·12	1 007	−·17	+0·04	44·25
49	Adobe	Colo.	1881	38 40 37·53	±0·07	1 576	−·26	+0·15	37·42
50	El Paso East Base	Colo.	1879	38 57 16·90	±0·10	1 994	−·34	−0·06	16·50

H. SYNOPSIS OF RESULTS FOR LATITUDE OF STATIONS, ETC.—Cont'd.

No.	Name of station.	State.	Year.	Observed latitude.	Probable error.	Approximate altitude of station.	Reduction to sea level.	Correction for variation of pole.	Final seconds of latitude.
				° ′ ″	″	m.	″	″	″
51	Colorado Springs	Colo.	1873	38 49 60·34	±0·12	1 822	−·31	−0·05	59·98
52	Pikes Peak	Colo.	1895	38 50 27·89	±0·09	4 301	−·72	+0·11	27·28
53	Mount Ouray	Colo.	1894	38 25 18·65	±0·08	4 254	−·71	+0·06	18·00
54	Treasury Mountain..................	Colo.	1893	39 00 48·01	±0·08	4 098	−·69	−0·07	47·25
55	Gunnison	Colo.	1893	38 32 44·86	±0·10	2 343	−·39	−0·08	44·39
56	Uncompahgre	Colo.	1895	38 04 16·39	±0·08	4 356	−·73	+0·08	15·74
57	Grand Junction	Colo.	1886	39 03 59·39	±0·07	1 406	−·24	−0·11	59·04
58	Tavaputs	Colo.	1891	39 32 17·35	±0·03	2 680	−·45	+0·22	17·12
59	Mount Waas	Utah	1893	38 32 29·70	±0·12	3 755	−·63	−0·07	29·00
60	Green River	Utah	1898	38 59 23·89	±0·06	1 250	−·21	−0·05	23·63
61	Patmos Head	Utah	1890	39 29 57·15	±0·06	3 003	−·51	+0·22	56·86
62	Mount Ellen	Utah	1891	38 07 24·66	±0·06	3 501	−·58	+0·09	24·17
63	Wasatch	Utah	1890	39 06 54·32	±0·06	3 398	−·57	+0·08	53·83
64	Mount Nebo	Utah	1887	39 48 32·90	±0·12	3 624	−·61	+0·02	32·31
65	Gunnison	Utah	1872	39 09 25·62	±0·05	1 568	−·26	+0·10	25·46
66	Ogden Peak	Utah	1888	41 11 59·60	±0·07	2 924	−·50	+0·12	59·22
67	Salt Lake City	Utah	1869	40 46 03·78	±0·05	1 328	−·22	−0·20	03·36
68	Ogden Observatory, United States Engineers	Utah	{1873 1874}	41 13 08·56	±0·03	1 338	−·23	0·00	08·33
69	Waddoup..............................	Utah	1892	40 54 22·11	±0·13	1 308	−·22	−0·16	21·73
70	Antelope	Utah	1892	40 57 40·49	±0·07	2 016	−·34	+0·01	40·16
71	Promontory	Utah	1892	41 17 48·28	±0·08	2 014	−·34	−0·17	47·77
72	Deseret	Utah	1892	40 27 31·93	±0·08	3 367	−·57	−0·11	31·25
73	Beaver	Utah	1872	38 16 23·28	±0·06	1 803	−·30	−0·08	22·90
74	Oasis.................................	Utah	1898	39 17 35·47	±0·08	1 435	−·24	+0·06	35·29
75	Ibepah	Utah	1889	39 49 39·35	±0·07	3 689	−·62	+0·24	38·97
76	Pilot Peak	Nev.	1889	41 01 08·26	±0·09	3 268	−·56	+0·13	07·83
77	Pioche	Nev.	1883	37 59 06·98	±0·09	2 679	−·45	+0·27	06·80
78	Pioche, United States Engineer Station	Nev.	1872	37 55 26·07	±0·07	1 811	−·30	+0·03	25·80
79	Diamond Peak.......................	Nev.	1881	39 35 04·13	±0·07	3 242	−·55	+0·07	03·65
80	Mount Callahan	Nev.	1881	39 42 32·32	±0·08	3 112	−·53	+0·13	31·92
81	Toiyabe Dome	Nev.	1880	38 49 54·55	±0·11	3 591	−·60	−0·04	53·91
82	Carson Sink	Nev.	1880	39 34 58·15	±0·08	2 681	−·45	−0·03	57·67
83	Observatory, Carson City	Nev.	1889	39 09 47·19	±0·13	1 421	−·24	+0·16	47·11
	Observatory, Carson City	Nev.	1893	47·60	±0·07	1 421	−·24	−0·07	47·29
	Adopted value	....	....	....	±0·06	....	....	....	47·25
84	Verdi	Nev.	1872	39 31 04·70	±0·07	1 480	−·25	−0·16	04·29
85	Lake Tahoe Southeast	Cal.	1893	38 57 19·76	±0·06	1 895	−·32	−0·07	19·37
86	Mount Conness	Cal.	1890	37 57 56·44	±0·06	3 830	−·64	+0·18	55·98
87	Round Top...........................	Cal.	1879	38 39 46·89	±0·08	3 166	−·53	−0·09	46·27
88	Mount Lola	Cal.	1879	39 25 58·00	±0·07	2 788	−·47	−0·16	57·37
89	Mocho	Cal.	1887	37 28 36·94	±0·05	1 248	−·21	−0·02	36·71
90	Marysville	Cal.	1898	39 08 12·48	±0·06	24	0	−0·21	12·27
91	Mount Hamilton, Lick Observatory, Coast and Geodetic Survey Station	Cal.	1888	37 20 29·10	±0·17	1 286	−·21	−0·04	28·85
92	Yolo Southeast Base.................	Cal.	1880	38 31 34·58	±0·07	22	0	−0·03	34·55
93	Yolo Northwest Base	Cal.	1880	38 40 37·29	±0·07	47	−·01	−0·03	37·25
94	Mount Diablo	Cal.	1876	37 52 49·63	±0·06	1 173	−·20	+0·17	49·60
95	Vaca	Cal.	1880	38 22 23·43	±0·06	730	−·12	−0·04	23·27
96	Monticello	Cal.	1880	38 39 46·46	±0·09	932	−·16	−0·04	46·26
97	San Francisco, Washington square...	Cal.	1873	37 47 56·97	±0·66	25	0	−0·07	56·90
98	San Francisco, Lafayette Park	Cal.	1888	37 47 28·08	±0·04	116	−·02	−0·06	28·00
	San Francisco, Lafayette Park	Cal.	{1891 1892}	.... 28·33	±0·01	116	−·02	....	28·31
99	San Francisco, Presidio, old station	Cal.	1852	37 47 35·96	±0·04	118	−·02	0	35·96

H. SYNOPSIS OF RESULTS FOR LATITUDE OF STATIONS, ETC.—Compl'td.

No.	Name of station.	State.	Year.	Observed latitude.	Probable error.	Approximate altitude of station.	Reduction to sea level.	Correction for variation of pole.	Final seconds of latitude.
				° ′ ″	″	m.	″	″	″
100	San Francisco, Presidio, new station	Cal.	1896	37 47 48·22	±0·05	130	−·02	+0·15	48·35
101	Mount Tamalpais	Cal.	1882	37 55 19·08	±0·08	791	−·13	+0·23	19·18
102	Mount Helena	Cal.	1876	38 40 01·05	±0·07	1 322	−·22	+0·22	01·05
103	Ross Mountain	Cal.	{1859 1860}	38 30 10·00	±0·04	672	−·11	+0·07	09·96
104	Sulphur Peak	Cal.	1859	38 45 44·57	±0·04	1 055	−·18	+0·03	44·42
105	Ukiah	Cal.	1897	39 08 54·40	±0·05	260	−·04	+0·23	54·59
106	Point Reyes	Cal.	1853	37 59 33·62	±0·13	430	−·07	+0·07	33·62
107	Bodega	Cal.	1853	38 18 20·21	±0·21	264	−·04	−0·06	20·11
108	Mendocino City	Cal.	1853	39 18 05·56	±0·12	18	0	−0·06	05·50
109	Point Arena	Cal.	1870	38 55 10·34	±0·19	7	0	−0·18	10·16

PART V.

THE RESULTS OF THE ASTRONOMIC DETERMINATIONS OF AZIMUTH.

CONTENTS OF PART V.

V. THE RESULTS OF THE ASTRONOMIC DETERMINATIONS OF AZIMUTH.

A. INTRODUCTION.

The azimuth, like the latitude determinations, antedate the time of the conception of the Transcontinental Triangulation, but they differ from them in the variety of instruments and methods used. This might have been anticipated from the fact that the proper selection of the method depends largely upon the kind of instrument the observer has at his disposal, as well as upon the season and time of day at which the observations are to be made. The relative advantages and disadvantages, or adaptability, of various methods and their respective instrumental requirements, together with formulæ and examples, are set forth in Appendix No. 14, Coast and Geodetic Survey Report for 1880, pp. 263 to 286.* Under the title "On the determination of an azimuth from micrometric observations of a close circumpolar star near elongation by means of a meridian transit or by means of a theodolite with eyepiece micrometer," Appendix No. 2, Part II, of the Coast and Geodetic Survey Report for 1891, pp. 15–19, contains an account of a method capable of great accuracy, which was first published as Bulletin No. 21 in December, 1890. In the great majority of cases the azimuth at a station was determined during its occupation for the measures of horizontal directions and the same instrument was used for both purposes. The following table gives the principal dimensions of the various instruments used:

Coast and Geodetic Survey number.	Kind of instrument.	† Number of microscopes.	Name of maker.	When made.	Diameter of horizontal circle.	Focal length.	Clear aperture.	Magnifying power.
					cm.	*cm.*	*cm.*	
1	Direction theodolite	3	Troughton & Simms	1836	75	115	7·5	(?)
2	Direction theodolite	3	Troughton	1817	60	75	5·2	30–40
5	Direction theodolite	3	Oertling	1873	50	98	7·4	80
113	Direction theodolite	3	Lingke & Co.	1876	50	90	7	75
114	Direction theodolite	3	Lingke & Co.	1876	50	{90 {67	7 5	{75 {32
115	Direction theodolite	3	Lingke & Co.	1876	50	100	7·4	40–95
10	Direction theodolite	{2, after 1886 3}	W. Würdemann (?)	1874	35	62	5·6	36
U. S. Lake Survey	Direction theodolite	3	Troughton & Simms	1871	35	60	5	(?)
16	Repeating theodolite	....	Gambey	1848 (?)	30	75	5·3	48
32	Repeating theodolite	....	Gambey	(?)	30	{56 {53	4·7 5·3	25 28–48
118	Direction theodolite	3	Fauth & Co.	1878	30	58	6	25–50
135	Direction theodolite	{2, after 1887 3}	Fauth & Co.	1880 (?)	30	49	6·5	25
147	Direction theodolite	2	Fauth & Co.	1886 (?)	30	77	6·2	28–37
3	Meridian telescope	....	E. Kübel	1876	....	80	7	72
7	Meridian telescope	...	W. Würdemann	1870	....	66	5	35–67
9	Meridian telescope	....	W. Würdemann	1870	...	65	5·2	43
13	Meridian telescope	....	W. Würdemann	1871	....	66	5·5	70

*A new edition of this Appendix has appeared in the Annual Report of the Superintendent for 1897–98. Appendix No. 7 by J. F. Hayford, assistant.

† Equidistant reading-microscopes.

For each azimuth station the following abstracts contain the individual results and all information needed to judge of the value of the determination. The apparent places of the stars used are taken directly from the American Ephemeris or derived from the second edition of Dr. B. A. Gould's Standard Places of Fundamental Stars (Washington, 1866), unless a statement is made to the contrary. The column headed "Position" in the summaries of results refers to the different positions of the horizontal circle of the theodolite during the observations, so distributed as to eliminate so far as possible systematic errors of graduation. The probable error of a resulting azimuth is determined from the differences between the resulting azimuth and the individual results from which it is derived, but no account has been taken of the probable error of the star's place, which is usually much smaller than the observing error. At a majority of the stations the effect of an uncertainty in the star's place as well as in the latitude has been practically eliminated by observing at hour angles about twelve hours apart. For stations at high altitudes (west of the Salina Base), where the azimuth mark was at a triangulation station, a correction for reduction to sea level has been applied, just as in the abstract of horizontal directions. Where the azimuth mark was used simply to connect the azimuth with the horizontal direction measures, no such correction was needed. A correction has been applied to the azimuths for variation of latitude and is given in the summary of results; for explanation and remarks see a similar correction to the latitude results in preceding part. At each station the azimuth of the mark is referred to a line of the triangulation for convenience in comparing with the corresponding geodetic azimuth. The stations are arranged in the order of longitude beginning with the easternmost.

B. ABSTRACT OF RESULTING AZIMUTHS.

I. EASTERN SHORE SERIES.

(1) CAPE HENLOPEN LIGHT-HOUSE, SUSSEX COUNTY, DELAWARE.

$\varphi = 38° \ 46'.7$. $\lambda = 75° \ 05'.0$ West of Greenwich.

Results for azimuth from observations of α Ursæ Minoris and λ Ursæ Minoris at various hour angles.—The 30-centimetre direction theodolite No. 135 was mounted on a brick pier, about 15 metres north of the light-house tower. Brandywine Shoal Light-House was used as azimuth mark, but the light, which was usually observed upon, was large and unsteady. A single result for azimuth is derived from a set of observations consisting of pointing on mark, pointing on star, reversal of instrument, pointing on star and pointing on mark, with noting of time and level readings for the star observations. The observations and field computation were made by O. B. French; the office computation by D. L. Hazard and C. C. Yates. The probable error of a single result for azimuth was found to be $\pm$ 1''.76 for α Ursæ Minoris and $\pm$ 0''.97 for λ Ursæ Minoris.

Summary of results for azimuth at Cape Henlopen Light-House, eccentric station, Delaware.

α Ursæ Minoris.

Date, 1897.	Position.	Series.	Mark W. of N.	Δ
			° ′ ″	″
Sept. 5	I	1	6 14 23·97	+0·76
		2	23·32	+0·11
5	II	1	26·61	+3·40
		2	28·32	+5·11
5	III	1	23·12	−0·09
		2	21·28	−1·93
6	IV	1	25·38	+2·17
		2	28·47	+5·26
6	V	1	25·83	+2·62
		2	25·46	+2·25
6	VI	1	24·90	+1·69
		2	22·08	−1·13
6	VII	1	24·46	+1·25
		2	23·27	+0·06
6	VIII	1	19·50	−3·71
		2	21·70	−1·51
7	IX	1	23·41	+0·20
		2	23·09	−0·12
7	X	1	25·66	+2·45
		2	24·09	+0·88
7	XI	1	20·15	−3·06
		2	21·13	−2·08
7	XII	1	17·98	−5·23
		2	21·77	−1·44
7	XIII	1	19·89	−3·32
		2	19·70	−3·51
8	XIV	1	23·38	+0·17
		2	21·99	−1·22
Mean			6 14 23·21	±0·33

λ Ursæ Minoris.

Date, 1897.	Position.	Series.	Mark W. of N.	Δ
			° ′ ″	″
Sept. 9	XV	1	6 14 23·14	+0·95
		2	22·73	+0·54
10	XVI	1	23·53	+1·34
		2	21·72	−0·47
10	XVII	1	24·79	+2·60
		2	22·22	+0·03
10	I	3	[16·28]	Rejected.
		4	23·01	+0·82
10	II	3	21·99	−0·20
		4	20·67	−1·52
10	III	3	22·24	+0·05
		4	24·05	+1·86
11	IV	3	21·92	−0·27
		4	20·83	−1·36
11	VI	3	22·22	+0·03
		4	24·55	+2·36
11	VIII	3	22·16	−0·03
		4	23·14	+0·95
11	XII	3	20·59	−1·60
		4	20·51	−1·68
11	XIII	3	19·18	−3·01
		4	20·84	−1·35
Mean			6 14 22·19	±0·21

There is not sufficient evidence of position errors to warrant a combination of the results by positions. The mean of the separate results for the two stars, weighted according to their probable errors, is 6° 14′ 22″·48 ± 0″·18; the indiscriminate mean of the 49 values, 6° 14′ 22″·77. The true value probably lies between these two, say their mean, 6° 14′ 22″·62 ± 0″·21, of which the probable error is obtained from the differences between it and the individual results. Applying the correction for diurnal aberration −0″·32, we have mark west of north 6° 14′ 22″·30 ± 0″·21, and azimuth of Brandywine Shoal Light-House from eccentric station—

	° ′ ″ ″
	173 45 37·70 ± 0·21
Reduction to center of light-house	− 20·37
Azimuth, Cape Henlopen Light-House to Brandywine Shoal Light-House	173 45 17·33 ± 0·21

(2) PRINCIPIO, MARYLAND.

$\varphi = 39° 35'·6$. $\lambda = 76° 00'·3$ West of Greenwich.

Results for azimuth from observations of α Ursæ Minoris near Eastern Elongation.—The 60-centimetre direction theodolite No. 2 was mounted over the triangulation station. The mark was at Carpenters Point, about 3½ miles south of the station, and consisted of the usual lamp, of which the light showed through an aperture in its

protecting box. A single result for azimuth is derived from a set of observations consisting of 3 pointings on the mark, reversal of instrument, 3 pointings on the mark, 4 to 6 pointings on the star, reversal of the instrument, followed by the same operations in the reverse order, with the necessary time and level readings. The observations were made by R. D. Cutts; computation by J. Main. Probable error of a single result ± 1″·75.

Summary of results for azimuth at Principio, Maryland.

Date, 1866.	Position.	Mark W. of S.	Δ	Date, 1866.	Position.	Mark W. of S.	Δ
		° ′ ″	″			° ′ ″	″
Aug. 15	II	3 05 08·47	+1·27	Aug. 27	V	3 05 08·35	+1·15
16	II	03·68	−3·52	29	V	10·02	+2·82
17	II	08·74	+1·54	31	V	08·93	+1·73
18	II	02·39	−4·81	Sept. 1	I	05·21	−1·99
20	III	07·50	+0·30	4	I	02·90	−4·30
22	III	07·80	+0·60	4	I	10·13	+2·93
23	III	09·49	+2·29	5	I	08·48	+1·28
24	IV	07·26	+0·06	5	I	[04 58·51]	Rejected.
25	IV	05·92	−1·28	6	I	07·06	−0·14
26	IV	03·35	−3·85	6	I	11·08	+3·88

	° ′ ″ ″
Mean, Mark West of South	3 05 07·20 ± 0·40
Diurnal aberration	+ 0·32
Azimuth of Mark	3 05 07·52
Angle between Turkey Point and Mark	1 30 24·01
Azimuth of Turkey Point	1 34 43·51

(3) CALVERT, MARYLAND.

$\varphi = 38° 21'·6$. $\lambda = 76° 23'·6$ West of Greenwich.

Results for azimuth from observations of α Ursæ Minoris near Eastern Elongation.— The 30-centimetre Gambey theodolite No. 16 was mounted on a yellow pine block over the triangulation station. The mark was across the bay at Meekins Neck, about 6 miles distant. A single result for azimuth is derived from a set of observations consisting of 12 repetitions of the angle between the mark and the star, 6 with telescope direct and 6 with telescope reversed, the star being observed alternately direct and reflected in mercury. Observer, A. T. Mosman; computer, James Main. Probable error of a single result ± 0″·71.

Summary of results for azimuth at Calvert, Maryland.

Date, 1871.	Mark E. of N.	Δ	Date, 1871.	Mark E. of N.	Δ
	° ′ ″	″		° ′ ″	″
Aug. 25	72 06 09·30	+0·69	Sept. 1	72 06 09·74	+1·13
25	07·23	−1·38	1	10·83	+2·22
25	08·42	−0·19	2	08·24	−0·37
25	07·54	−1·07	2	07·45	−1·16
31	08·85	+0·24	2	07·73	−0·88
31	07·46	−1·15	2	07·92	−0·69
31	08·74	+0·13	3	07·78	−0·83
31	09·44	+0·83	3	08·49	−0·12
Sept 1	09·69	+1·08	3	10·10	+1·49

	° ′ ″ ″
Mean	72 06 08·61 ± 0·17
Diurnal aberration	+ 0·32
Azimuth of Meekins Neck	252 06 08·93 ± 0·17

(4) MARRIOTT, MARYLAND.

$\varphi = 38° 52'.4$. $\lambda = 76° 36'.6$ West of Greenwich.

Results for azimuth from observations of α, δ, and λ Ursæ Minoris near Eastern Elongation, and α, β, θ, and ζ Ursæ Minoris and α Ursæ Majoris, near Western Elongation.—The 60-centimetre direction theodolite No. 2 was mounted over the triangulation station. Observers, A. D. Bache and J. Hewston, jr.; G. Davidson and J. Main, computers. A single result for azimuth is derived from a set of observations consisting of about a dozen pointings on the star, one-half with telescope direct and the other half with telescope reversed, and corresponding pointings on the mark. Probable error of a single result $\pm 1''.92$.

Summary of results for azimuth at Marriott, Maryland.

Stars near Eastern Elongation.					Stars near Western Elongation.				
Date, 1849.	Star.	Position.	Mark W. of N.	Δ	Date, 1849.	Star.	Position.	Mark W. of N.	Δ
			° ′ ″	″				° ′ ″	″
June 4	δ Urs. Min.	IV	0 58 25·61	−1·77	June 5	α Urs. Min.	V	0 58 23·05	−5·51
4	λ Urs. Min.	III	25·48	−1·90	10	β Urs. Min.	VII	29·54	+0·98
5	δ Urs. Min.	II	31·37	+3·99	11	α Urs. Maj.	VI	29·68	+1·12
5	λ Urs. Min.	I	25·76	−1·62	11	β Urs. Min.	VI	29·75	+1·19
5	α Urs. Min.	XI	28·10	+0·72	16	β Urs. Min.	VIII	28·77	+0·21
8	δ Urs. Min.	IX	23·15	−4·23	16	θ Urs. Min.	IX	25·12	−3·44
8	λ Urs. Min.	X	29·09	+1·71	18	β Urs. Min.	X	30·71	+2·15
10	α Urs. Min.	VIII	30·50	+3·12	18	ζ Urs. Min.	XI	31·84	+3·28
Mean			0 58 27·38	±0·68	Mean			0 58 28·56	±0·71

	° ′ ″ ″
Mean, Mark West of North	0 58 27·97±0·48
Mark West of South	179 01 32·03
Correction for diurnal aberration	+0·31
Azimuth of Mark	179 01 32·34
Angle between Hill and Mark	82 23 48·98
Azimuth of Hill	96 37 43·36

(5) WEBB, MARYLAND.

$\varphi = 39° 05'.4$. $\lambda = 76° 40'.5$ West of Greenwich.

Results for azimuth from observations of α Ursæ Minoris near Eastern and Western Elongations.—The 75-centimetre direction theodolite No. 1 was mounted over the triangulation station. The mark was about a mile distant. Observers, A. D. Bache and G. W. Dean; computer, J. Main. A single result for azimuth is derived from a set of observations consisting of 6 pointings on the mark, half with telescope direct and half with telescope reversed, 12 pointings on the star, half of these being direct and half reversed; finally 6 more pointings on the mark. Probable error of a single result $\pm 0''.67$.

Summary of results for azimuth at Webb, Maryland.

α Ursæ Minoris near Eastern Elongation.				α Ursæ Minoris near Western Elongation.			
Date, 1850.	Position.	Mark E. of N.	Δ	Date, 1850.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Oct. 29	I	6 07 45·46	+0·04	Oct. 29	I	6 07 45·45	−0·24
Nov. 1	II	46·62	+1·20	Nov. 9	III	44·46	−1·23
10	III	45·97	+0·55	13	IV	47·59	+1·90
13	IV	44·75	−0·67	14	V	45·23	−0·46
14	V	44·31	−1·11	18	II	45·73	+0·04
Mean		6 07 45·42	±0·28	Mean		6 07 45·69	±0·35

	° ′ ″ ″
Mean, Mark E. of N. 6° 07′ 45″·56 or W. of S.	186 07 45·56 ± 0·21
Diurnal aberration	+ 0·32
Azimuth of Mark	186 07 45·88
Angle between Soper and Mark	97 07 56·64
Azimuth of Soper	88 59 49·24

2. ALLEGHENY SERIES.

(6) HILL, MARYLAND.

$\phi = 38° 53'·9.$ $\lambda = 76° 52'·8$ West of Greenwich.

Results for azimuth from observations of α Ursæ Minoris near Eastern and Western Elongations and λ Ursæ Minoris near Upper Culmination.—The 75-centimetre direction theodolite was mounted over the triangulation station. The mark was in line to station Webb. Observers, A.D. Bache and G. W. Dean; computer, J. Main. A single result for azimuth is derived from a set of observations consisting of 6 pointings on the mark, half with telescope direct and half with telescope reversed, 10 pointings on the star, half direct and half reversed, and finally 6 more pointings on the mark. Probable error of a single result = ± 0″·83. The results from λ Ursæ Minoris are considered inferior and are therefore not used.

Summary of results for azimuth at Hill, Maryland.

α Ursæ Minoris near Eastern Elongation.				α Ursæ Minoris near Western Elongation.				λ Ursæ Minoris near U.C.		
Date, 1850.	Position.	Mark E. of N.	Δ	Date, 1850.	Position.	Mark E. of N.	Δ	Date, 1850.	Position.	Mark E. of N.
		° ′ ″	″			° ′ ″	″			° ′ ″
Sept. 27	III	39 46 56·53	−0·30	Sept. 26	III	39 46 59·34	+1·57	Sept. 17	V	39 46 60·22
28	II	54·63	−2·20	27	II	57·38	−0·19	21	I	59·86
29	IV	57·07	+0·24	28	IV	57·96	+0·19	Oct. 4	II	62·96
Oct. 3	I	58·35	+1·52	Oct. 2	I	56·50	−1·27	These results not used.		
5	V	57·55	+0·72	4	V	57·67	−0·10			
Mean		39 46 56·83	±0·42	Mean		39 46 57·77	±0·31			

	° ′ ″
Mean 39° 46′ 57″·30 E. of N., or	219 46 57·30 W. of S.
Mean corrected for diurnal aberration	219 46 57·62 ± 0″·26.
Angle between Mark and Webb	0 00 00·27.
Azimuth of Webb	219 46 57·89.

(7) SOPER, MARYLAND.

$\varphi = 39^\circ\ 05'.2.$ $\lambda = 76^\circ\ 57'.0$ West of Greenwich.

Results for azimuth from observations of α Ursæ Minoris near Lower Culmination, λ Ursæ Minoris near Eastern Elongation, and δ Ursæ Minoris near Western Elongation.—The 75-centimetre direction theodolite No. 1 was mounted over the triangulation station. The mark was 442 metres to the south of the station. Observer, A. D. Bache; computer, J. Main. A single result for azimuth is derived from a set of observations consisting of 6 pointings on the mark, 10 pointings on the star, half with telescope direct and half with telescope reversed, 6 pointings on the mark, taken just before culmination, followed by similar operations immediately after culmination. For the stars at elongation the operations are not repeated. Probable error of a single result = ± 0″.92.

Summary of results for azimuth at Soper, Maryland.

Date, 1850.	Star.	Position.	Mark E. of N.	Δ	Date, 1850.	Star.	Position.	Mark E. of N.	Δ
			° ′ ″	″				° ′ ″	″
July 4	λ Urs. Min. E. E.	III	178 19 38.03	−0.19	July 11	α Urs. Min. L. C.	IV	178 19 37.00	−1.22
4	δ Urs. Min. W. E.	III	38.23	+0.01	19	α Urs. Min. L. C.	V	39.01	+0.79
5	α Urs. Min. L. C.	III	38.58	+0.36	23	α Urs. Min. L. C.	V	40.10	+1.88
8	α Urs. Min. L. C.	III	37.62	−0.60	25	α Urs. Min. L. C.	I	40.29	+2.07
10	α Urs. Min. L. C.	IV	37.40	−0.82	29	α Urs. Min. L. C.	II	35.96	−2.26

	° ′ ″	″
Mean	178 19 38.22	± 0.29
Azimuth of Mark (corrected for diurnal aberration)	358 19 38.54	
Angle between Webb and Mark	89 30 15.08	
Azimuth of Webb	268 49 23.46	

(8) SEATON, DISTRICT OF COLUMBIA.

$\phi = 38^\circ\ 53'.4.$ $\lambda = 77^\circ\ 00'.0$ West of Greenwich.

Results for azimuth from observations of α Ursæ Minoris at various hour angles.—The 75-centimetre direction theodolite was mounted over the triangulation station. The mark was on the tower of the Soldiers' Home, about 3½ miles distant. Observer, C. O. Boutelle; computer, James Main. A single result for azimuth is derived from a set of observations consisting of 8 pointings on the mark and 8 pointings on the star, one-half of these with telescope direct and one-half in the reversed position. The star was observed alternately direct and reflected in mercury. Probable error of a single result = ± 0″.72.

Summary of results for azimuth at Seaton, District of Columbia.

Date.	Position.	Series.	Mark W. of N.	Mean of position.	Δ	Date.	Position.	Series.	Mark W. of N.	Mean of position.	Δ
1868.			° ′ ″	″	″	1868.			° ′ ″	″	″
Dec. 17	II	1	10 01 15·55			Dec. 27	VI	1	10 01 14·65		
17	II	2	13·50			27	VI	2	13·50		
17	II	3	13·50			27	VI	3	13·30		
17	II	4	15·05	14·40	+0·67	27	VI	4	14·10		
18	III	1	12·40			27	VI	5	14·70	14·05	+0·32
18	III	2	13·20			1869.					
18	III	3	13·00			Jan. 5	VII	1	15·75		
18	III	4	13·55			5	VII	2	14·85		
18	III	5	13·60	13·15	−0·58	5	VII	3	14·35		
19	IV	1	13·00			5	VII	4	13·45		
19	IV	2	11·40			5	VII	5	13·45	14·37	+0·64
19	IV	3	13·90			6	I	1	14·05		
21	IV	4	14·35			6	I	2	14·25		
21	IV	5	13·80	13·29	−0·44	6	I	3	14·15		
21	V	1	11·95			6	I	4	15·10		
21	V	2	13·20			6	I	5	13·70	14·25	+0·52
21	V	3	13·25								
21	V	4	10·70								
21	V	5	13·80	12·58	−1·15						

	° ′ ″	″
Mean	10 01 13·73	±0·18
Aberration	−0·32	
Azimuth of Mark	169 58 46·59	
Angle between Mark and Hill	95 34 07·17	
Azimuth of Hill	265 32 53·76	

(9) CAUSTEN, DISTRICT OF COLUMBIA.

$\varphi = 38° 55'·5.$ $\lambda = 77° 04'·4$ West of Greenwich.

Results for azimuth from observations on α Ursæ Minoris near Eastern Elongation and near Lower Culmination.—The 75-centimetre direction theodolite No. 1 was mounted over the triangulation station. The azimuth mark was about a quarter of a mile distant. Observer, G. W. Dean; computer, James Main. A single result for azimuth at elongation is derived from a set of observations consisting of 6 pointings on the mark, one-half with telescope direct and the other half in the reversed position, 10 pointings on the star, telescope, half direct and half reversed, finally 6 more pointings on the mark. At culmination two such sets, one before and the other after culmination, are combined to get a single result.

Summary of results for azimuth at Causten, District of Columbia.

Star near Eastern Elongation.				Star near Lower Culmination.			
Date, 1851.	Position.	Mark E. of N.	Δ	Date, 1851.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
May 9	I	30 52 60·78	+0·16	May 26	V	30 52 57·41	−1·88
12	II	59·25	−1·37	31	IV	58·07	−1·22
14	III	61·84	+1·22	June	III	60·44	+1·15
				4	II	59·27	−0·02
				7	I	61·27	+1·98
Mean		30 52 60·62	±0·51	Mean		30 52 59·29	±0·48
Aberration		+0·32		Aberration		+0·31	

	° ′ ″
Mark E. of N. 30° 53′ 00″·27 ± 0″·37 or	210 53 00·27 W. of S.
Angle between Mark and Soper	0 01 41·51
Azimuth of Soper	210 54 41·78

(10) SUGAR LOAF, MARYLAND.

$\varphi = 39° 15'·7$. $\lambda = 77° 23'·6$ West of Greenwich.

Results for azimuth from observations of α Ursæ Minoris at various hour angles.—The 50-centimetre direction theodolite No. 113 was mounted over the triangulation station. The mark was near the railroad station at Barnesville, 3·8 miles distant. Observers, C. O. Boutelle and F. D. Granger; computer, James Main. A single result for azimuth is derived from a set of observations consisting of a pointing on the mark followed by pointings on the star and its image reflected in mercury, reversal of instrument, pointings on the star and its reflected image, concluding with a pointing on the mark. Probable error of a single result $= \pm 1''·02$.

Summary of results for azimuth at Sugar Loaf, Maryland.

Date, 1879.	Position.	Series.	Mark E. of N.	Mean of position.	Δ	Date, 1879.	Position.	Series.	Mark E. of N.	Mean of position.	Δ
			° ′ ″	″	″				° ′ ″	″	″
Sept. 19	I	1	167 01 60·45			Oct. 16	VI	3	167 01 59·90		
19	I	2	58·39	60·20	+0·24	16	VII	1	60·95		
19	I	3	61·76			16	VII	2	58·99	60·23	+0·27
24	II	1	62·50			16	VII	3	60·76		
24	II	2	61·00	60·34	+0·38	16	VIII	1	58·39		
25	II	3	57·51			16	VIII	2	61·37	59·69	−0·27
Oct. 14	III	1	58·50			16	VIII	3	59·32		
14	III	2	59·42	58·46	−1·50	31	IX	1	60·07		
14	III	3	57·47			31	IX	2	59·23	59·23	−0·73
14	IV	1	59·16			31	IX	3	58·39		
14	IV	2	58·62	59·05	−0·91	Nov. 9	X	1	60·42		
14	IV	3	59·36			9	X	2	62·23	61·58	+1·62
14	V	1	60·51			9	X	3	62·08		
14	V	2	58·83	59·56	−0·40	9	XI	1	61·54		
14	V	3	59·35			9	XI	2	60·17	61·63	+1·67
Oct. 16	VI	1	57·58			9	XI	3	63·17		
16	VI	2	61·25	59·58	−0·38						

	° ′ ″ ″
Mean	167 01 59·96 ± 0·20
Diurnal aberration	·0·32
Azimuth of Mark	347 02 00·28
Angle between Mark and Bull Run	45 27 16·51
Azimuth of Bull Run	32 29 16·79

(11) MARYLAND HEIGHTS, MARYLAND.

$\varphi = 39^\circ\ 20'\cdot4$. $\lambda = 77^\circ\ 43'\cdot0$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 75-centimetre direction theodolite No. 1 was mounted over the triangulation station. The azimuth mark was on a hill back of Knoxville, about 3½ miles distant. Observer, C. O. Boutelle; computer, James Main. A single result for azimuth is derived from a set of observations consisting of a pointing on the mark, pointings on the star and its image reflected from mercury, reversal of instrument, pointings on the star and its reflected image, pointing on the mark. Probable error of a single result = $\pm 1''\cdot10$.

Summary of results for azimuth at Maryland Heights, Maryland.

Date, 1870.	Position.	Series.	Mark E. of N.	Mean of position.	Δ	Date, 1870.	Position.	Series.	Mark E. of N.	Mean of position.	Δ
			° ′ ″	″	″				° ′ ″		″
Oct. 9	III	1	108 14 41·37			Oct. 16	VII	4	108 14 45·63		
9	III	2	42·67			16	VII	5	43·32		
9	III	3	41·86	43·10	−0·36	21	I	1	45·45		
9	III	4	44·85			21	I	2	45·71		
9	III	5	44·75			21	I	3	45·65	45·15	+1·69
14	V	1	45·92			21	I	4	42·55		
14	V	2	43·34			21	I	5	46·37		
14	V	3	44·43	43·82	+0·36	22	II	1	42·09		
14	V	4	42·67			22	II	2	41·41		
14	V	5	42·75			22	II	3	42·90	42·55	−0·91
15	VI	1	41·50			22	II	4	42·48		
15	VI	2	40·39			22	II	5	43·86		
15	VI	3	40·54	42·40	−1·06	23	IV	1	41·97		
15	VI	4	44·79			23	IV	2	41·45		
15	VI	5	44·80			23	IV	3	45·32	43·33	−0·13
16	VII	1	43·62			23	IV	4	43·95		
16	VII	2	42·98			23	IV	5	43·96		
16	VII	3	43·67	43·84	+0·38						

	° ′ ″	″
Mean	108 14 43·46	
From all values		±0·18
And from positions		±0·24
Diurnal aberration	+0·32	
Azimuth of Mark	288 14 43·78 ± 0·18	
Angle between Mark and Bull Run	70 28 23·10	
Azimuth of Bull Run	358 43 06·88	

(12) BULL RUN, VIRGINIA.

$\varphi = 38^\circ\ 52'\cdot9$. $\lambda = 77^\circ\ 42'\cdot2$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 75-centimetre direction theodolite No. 1 was mounted over the triangulation station. The azimuth mark was on High Point Mountain about 1¼ miles distant. Observer, C. O. Boutelle; computer, James Main. A single result for azimuth is derived from a set of observations consisting of a pointing on the mark, pointings on the star, and its image reflected in mercury, reversal of instrument, pointings on the star, and its reflected image, and finally a pointing on the mark. Probable error of a single result = $\pm 1''\cdot20$.

Summary of results for azimuth at Bull Run, Virginia.

Date. 1871.	Position.	Series.	Mark W. of N.	Mean of position.	Δ	Date. 1871.	Position.	Series.	Mark W. of N.	Mean of position.	Δ
			° ′ ″	″	″				° ′ ″	″	″
Oct. 13	I	1	158 36 28·56			Oct. 22	IV	4	158 36 29·71		
13	I	2	28·78			22	IV	5	28·26		
13	I	3	32·63	29·84	−0·14	23	V	1	28·11		
14	I	4	30·57			23	V	2	30·04		
14	I	5	28·67			23	V	3	28·40	28·59	−1·39
17	II	1	33·63			23	V	4	28·10		
19	II	2	29·88			23	V	5	28·31		
19	II	3	30·91	32·05	+2·07	Nov. 2	VI	1	33·40		
19	II	4	33·25			2	VI	2	33·06		
19	II	5	32·56			2	VI	3	31·32	31·75	+1·77
20	III	1	28·83			2	VI	4	29·48		
20	III	2	31·56			2	VI	5	31·47		
20	III	3	30·02	29·65	−0·33	3	VII	1	28·93		
20	III	4	28·72			3	VII	2	31·06		
20	III	5	29·13			3	VII	3	30·12	29·49	−0·49
22	IV	1	28·18			3	VII	4	28·77		
22	IV	2	27·94			3	VII	5	28·58		
22	IV	3	28·35	28·49	−1·49						

	° ′ ″	″
Mean	158 36 29·98	
From all values		±0·20
And from positions		±0·36
Mean corrected for diurnal aberration	158 36 29·66	±0·20
Azimuth of Mark	21 23 30·34	
Angle between Mark and Peach Grove	242 29 57·81	
Azimuth of Beach Grove	263 53 28·15	

(13) Clark, Virginia.

$\varphi = 38° 18'.7$ $\lambda = 78° 00'.2$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 75-centimetre direction theodolite No. 1 was mounted over the triangulation station. The azimuth mark was at Rapidan railroad station, nearly 5 540 metres distant. Observer, C. O. Boutelle; computer, James Main. A single result for azimuth is derived from a set of observations consisting of a pointing on the mark, pointings on the star and its image reflected from mercury, reversal of instrument, pointings on the star, and its reflected image, and finally a pointing on the mark. Probable error of a single result $= \pm 1''.09$.

Summary of results for azimuth at Clark, Virginia.

Date, 1871.	Position.	Series.	Mark W. of N.	Mean of position.	Δ	Date, 1871.	Position.	Series.	Mark W. of N.	Mean of position.	Δ
			° ′ ″	″	″				° ′ ″	″	″
Aug. 7	III	1	85 30 57·05			Aug. 15	VI	4	85 30 59·04		
10	III	2	57·79			15	VI	5	60·41		
10	III	3	58·48	58·53	−1·11	18	VII	1	59·23		
10	III	4	60·12			18	VII	2	59·30		
10	III	5	59·20			18	VII	3	61·51	59·73	+0·09
11	IV	1	58·89			18	VII	4	59·81		
11	IV	2	58·64			18	VII	5	58·78		
11	IV	3	61·35	61·03	+1·39	25	I	1	59·57		
11	IV	4	62·73			25	I	2	61·35		
11	IV	5	63·53			25	I	3	59·91	59·96	+0·32
14	V	1	57·44			25	I	4	59·65		
14	V	2	62·33			25	I	5	59·31		
14	V	3	63·46	60·46	+0·82	30	II	1	58·52		
14	V	4	59·80			30	II	2	57·56		
14	V	5	59·27			30	II	3	57·49	58·47	−1·17
15	VI	1	58·43			30	II	4	59·41		
15	VI	2	58·81			30	II	5	59·37		
15	VI	3	59·70	59·28	−0·36						

	° ′ ″	″
Mean	85 30 59·64	
From all values		±0·18
And from positions		±0·24
Diurnal aberration	−0·32	
Azimuth of Mark	94 29 00·68	±0·18
Angle between Mark and Bull Run	107 50 27·09	
Azimuth of Bull Run	202 19 27·77	

(14) LONG MOUNT, VIRGINIA.

$\varphi = 37° \ 17'.4$. $\lambda = 79° \ 05'.2$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 35-centimetre direction theodolite No. 10 was mounted over the triangulation station. The mark was in the belfry of the court-house at Lynchburg, about 10 miles distant. Observer, A. T. Mosman; computer, James Main. A single result for azimuth is derived from a set of observations consisting of one reading of the mark, readings of the star, and its image reflected from mercury, reversal of the instrument, readings of the star, and its reflected image, and finally a reading of the mark. Probable error of a single result $= \pm 1''.54$.

Summary of results for azimuth at Long Mount, Virginia.

Date, 1875.	Position.	Series.	Mark W. of N.	Mean of position.	△
			° ′ ″	″	″
Nov. 13	I	1	20 48 11·90		
13	I	2	07·92	09·91	−3·20
13	II	1	11·11		
13	II	2	10·79	10·95	−2·16
13	III	1	13·31		
17	III	2	14·52	13·91	+0·80
17	IV	1	16·06		
17	IV	2	17·51	16·78	+3·67
17	V	1	14·22		
17	V	2	15·35	14·78	+1·67
17	VI	1	15·04		
17	VI	2	14·15	14·60	+1·49
17	VII	1	11·90		
17	VII	2	15·35	13·63	+0·52
17	VIII	1	15·93		
17	VIII	2	16·79	16·36	+3·25
17	IX	1	14·36		
17	IX	2	12·53	13·70	+0·59
18	X	1	16·77		
18	X	2	14·27	15·52	+2·41
18	XI	1	13·27		
18	XI	2	15·45	14·36	+1·25
18	XII	1	07·98		
18	XII	2	10·85	09·42	−3·69
Nov. 18	XIII	1	20 48 11·50		
18	XIII	2	10·05	10·78	−2·33
18	XIV	1	13·20		
22	XIV	2	15·18	14·19	+1·08
22	XV	1	13·01		
22	XV	2	13·25	13·13	+0·02
22	XVI	1	12·61		
27	XVI	2	15·90	14·25	+1·14
23	XVII	1	10·12		
23	XVII	2	12·03	11·08	−2·03
23	XVIII	1	12·42		
23	XVIII	2	10·20	11·31	−1·80
23	XIX	1	12·74		
23	XIX	2	11·12	11·93	−1·18
23	XX	1	11·40		
23	XX	2	13·52	12·46	−0·65
25	XXI	1	14·96		
25	XXI	2	13·08	14·02	+0·91
25	XXII	1	15·26		
25	XXII	2	12·75	14·00	+0·89
25	XXIII	1	09·98		
27	XXIII	2	10·78	10·38	−2·73

	° ′ ″	″
Mean	20 48 13·11	
From all values		±0·23
And from positions		±0·28
Diurnal aberration	−0·32	
Azimuth of Mark	159 11 47·21	±0·23
Angle between Mark and Spear	64 16 54·53	
Azimuth of Spear	223 28 41·74	

(15) ELLIOTT KNOB, VIRGINIA.

$\varphi = 38^\circ\ 10'\cdot0$. $\lambda = 79^\circ\ 18'\cdot9$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 30-centimetre direction theodolite No. 114 was mounted over the triangulation station. A collimator mounted on a brick pier 29 feet distant was used as a mark. Observer, A. T. Mosman; computer, James Main. A single result for azimuth is derived from a set of observations consisting of a pointing on the mark, pointings on the star and its image reflected from mercury, then reversal of instruments, followed by similar observations of star and mark. Probable error of a single result = $\pm$ 1″·50.

Summary of results for azimuth at Elliott Knob, Virginia.

Date, 1878.	Position.	Series.	Mark E. of N.	Mean of position.	Δ	Date, 1878.	Position.	Series.	Mark E. of N.	Mean of position.	Δ
			° ′ ″	″	″				° ′ ″	″	″
Aug. 2	I	1	1 41 36·1			Aug. 3	VI	1	1 41 35·2		
2	I	2	33·1	34·9	+0·4	3	VI	2	37·1	35·8	+1·3
2	I	3	35·4			3	VI	3	35·2		
2	II	1	37·8			3	VII	1	34·2		
2	II	2	33·6	34·5	0·0	3	VII	2	32·4	32·5	−2·0
2	II	3	32·1			3	VII	3	31·0		
3	III	1	35·4			4	VIII	1	33·9		
3	III	2	35·5	34·1	−0·4	4	VIII	2	34·3	33·6	−0·9
3	III	3	31·4			4	VIII	3	32·6		
3	IV	1	35·9			4	IX	1	36·1		
3	IV	2	38·2	37·5	+3·0	4	IX	2	32·4	34·6	+0·1
3	IV	3	38·3			4	IX	3	35·3		
3	V	1	34·1			4	X	1	32·6		
3	V	2	36·0	36·1	+1·6	4	X	2	30·8	31·6	−2·9
3	V	3	38·1			4	X	3	31·4		

	° ′ ″	″
Mean	1 41 34·52	
From all values		±0·27
From positions		±0·36
Diurnal aberration	∓0·32	
Azimuth of Mark (collimator)	181 41 34·84	±0·27
Angle between Mark and Humpback	121 43 49·53	
Azimuth of Humpback	303 25 24·37	

(16) KEENEY, WEST VIRGINIA.

$\varphi = 37° 46'·4$. $\lambda = 80° 42'·3$ West of Greenwich.

Three separate determinations of azimuth were made at this station by A. T. Mosman in September, 1880.

(1) *Results for azimuth from observations of Polaris at various hour angles within one hour of Eastern Elongation.*—The 50-centimetre direction theodolite No. 114 was mounted over the triangulation station. The mark was on Little Sewall Mountain, about 9·56 miles distant. Observer, A. T. Mosman; computers, A. S. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of three pointings on the mark, three pointings on the star, followed by reversal of instrument and similar pointings on star and mark. The probable error of a single result = ± 1″·14.

(1) *Summary of results of first determination.*

Date, 1880.	Position.	Mark E. of N.	Δ	Date, 1880.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Sept. 10	VIII	1 41 48·79	+0·50	Sept. 15	III	1 41 48·04	−0·25
10	VII	45·07	−3·22	15	IV	49·05	+0·76
13	IX	47·95	−0·34	15	V	50·22	+1·93
13	X	47·91	−0·38	15	VI	46·36	−1·93
13	XI	47·91	−0·38	19	VII	51·29	+3·00
14	I	49·60	+1·31	19	VIII	48·96	+0·67
14	II	46·62	−1·67				

Mean 1° 41′ 48″·29 ± 0″·31

(2) *Results for azimuth from micrometric measures of the angle between the mark and Polaris at Eastern Elongation.*—Instrument and mark as in the first determination. A shorter telescope carrying an eyepiece micrometer was substituted for the one ordinarily used. One turn of eyepiece micrometer = 77″·65.

(3) Meridian telescope No. 13 was mounted at a distance of 23·165 metres from the triangulation station and exactly in line to the azimuth mark. One turn of eyepiece micrometer = 77·848. Observer, A. T. Mosman; computers, A. S. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of three bisections of the mark with the micrometer thread, three bisections of the star, followed by reversal of the telescope and similar readings of the star and mark. The probable error of such a set was found to be ± 0″·58 for theodolite No. 114 and ± 0″·75 for meridian telescope No. 13.

(2) *Summary of results of second determination.*			(3) *Summary of results of third determination.*		
Date, 1880.	Mark E. of N.	Δ	Date, 1880.	Mark E of N.	Δ
	° ′ ″	″		° ′ ″	″
Sept. 16	1 41 48·36	−0·74	Sept. 21	1 41 48·96	−0·34
16	48·14	−0·96	21	49·04	−0·26
16	48·84	−0·26	21	51·41	+2·11
16	48·09	−1·01	21	48·60	−0·70
16	49·39	+0·29	21	49·54	+0·24
16	48·07	−1·03	21	51·17	+1·87
18	50·62	+1·52	22	48·02	−1·28
18	49·55	+0·45	22	47·63	−1·67
18	49·26	+0·16	22	49·75	+0·45
18	50·35	+1·25	22	48·95	−0·35
18	49·62	+0·52	22	49·29	−0·01
18	48·89	−0·21	22	49·26	−0·04
Mean	1 41 49·10	±0″·17	Mean	1 41 49·30	±0″·22

Summary of results for azimuth at Keeney, West Virginia.

	°	′	″	″
(1) Mark, East of North	1	41	48·29	± 0·31
(2) Mark, East of North			49·10	± 0·17
(3) Mark, East of North			49·30	± 0·22
Mean, Mark East of North	1	41	48·90	± 0·21
Diurnal aberration			+ 0·32	
Azimuth of Mark	181	41	49·22	± 0·21
Angle between Mark and Bald Knob	75	22	46·72	
Azimuth of Bald Knob	257	04	35·94	

(17) PINEY, WEST VIRGINIA.

$\varphi = 38° 26'.7$ $\lambda = 82° 03'.5$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles near Eastern Elongation.—The 50-centimetre direction theodolite No. 114 was mounted at the triangulation station. The azimuth mark was at station Gebhardt, about 12 miles distant. Observers, A. T. Mosman and W. B. Fairfield; computer, L. A. Bauer. A single result for azimuth is derived from a set of observations consisting of 3 pointings on the mark, 3 pointings on the star, followed by reversal of instrument and similar pointings on star and mark. Probable error of a single result = $\pm 0''.94$. The observations of September 19 are given only one-half weight on account of the extremely unfavorable conditions of the weather.

Summary of results for azimuth at Piney, West Virginia.

Date, 1883.	Position.	Mark W. of N.	Mean of position.	v	Date, 1883.	Position.	Mark W. of N.	Mean of position.	v
		° ′ ″	″	″			° ′ ″	″	″
Sept. 9	I	60 55 27.83			Sept. 15	VII	60 55 29.56		
9	I	30.24	29.04	+0.25	15	VII	29.88	29.72	+0.93
9	II	29.22			15	VIII	29.21		
10	II	28.41			15	VIII	29.20	29.20	+0.41
10	II	28.20	28.61	−0.18	15	IX	25.72		
10	III	28.83			15	IX	25.90		
10	III	27.48	28.16	−0.63	22	IX	27.09	26.24	−2.55
14	IV	29.78			19	X	24.45		
14	IV	30.10	29.94	+1.15	19	X	26.66		
14	V	28.96			19	X	27.23	26.11	−2.68
14	V	29.10	29.03	+0.24	22	XI	28.58		
14	VI	30.37			22	XI	28.72	28.65	−0.14
14	VI	30.92	30.64	+1.85					

	° ′ ″	″
Weighted position mean	60 55 28.79	±0.26
Diurnal aberration	-0.32	
Azimuth of Gebhardt	119 04 31.53	±0.26

3. OHIO SERIES.

(18) GOULD, OHIO.

$\varphi = 38° 38'.5$. $\lambda = 82° 49'.9$ West of Greenwich.

Results for azimuth from micrometric measures of the angle between Polaris near Eastern Elongation and an elongation mark.—Meridian telescope No. 7 was mounted on a wooden block 61.652 metres from the triangulation station, but accurately in line with the mark, which was about 2 miles distant. Observer, A. T. Mosman; computer, L. A. Bauer. A single result for azimuth is derived from a set of observations consisting of 5 bisections of the mark with the movable thread of the eyepiece micrometer, followed by 5 bisections of the star; then reversal of the telescope and 5 more bisections of star and mark. Probable error of the result from one night = $\pm 0''.58$.

Summary of results for azimuth at Gould, Ohio.

Date, 1885.	Mark E. of N.	Mean of night.	Δ	Date, 1885.	Mark E. of N.	Mean of night.	Δ
	° ′ ″	″	″		° ′ ″	″	″
Sept. 14	1 39 58·77			Sept. 17	1 39 57·89		
14	59·39			17	57·06		
14	58·21			17	57·50		
14	59·17	58·88	+0·72	17	58·23		
15	59·95			18	57·69	57·67	−0·49
15	59·94			18	57·33		
15	58·57			18	57·89		
15	58·71			18	56·47		
15	59·16	59·27	+1·11	18	56·90	57·26	−0·90
16	57·35						
16	57·57						
16	57·66						
16	58·58						
16	57·38	57·71	−0·45				

	° ′ ″	″
Mean	1 39 58·15	±0·26
Diurnal aberration	+0·32	
Reduction to triangulation station	−0·05	
Azimuth of Mark	181 39 58·43	±0·26
Angle between Howland and Mark	96 50 45·07	
Azimuth of Howland	84 49 13·36	

(19) MINERVA, KENTUCKY.

$\varphi = 38° 42'.5$. $\lambda = 83° 55'.1$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 30-centimetre direction theodolite No. 118 was mounted over the triangulation station. The azimuth mark was on the tower of the court-house at Georgetown, about 13 miles distant. Observer, A. T. Mosman; computer, L. A. Bauer. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 1 pointing on the star, and 1 on its image reflected from mercury, reversal of the instrument followed by similar pointings on the star and mark. Probable error of a single result $= \pm 1''.54$.

Summary of results for azimuth at Minerva, Kentucky.

Date, 1887.	Position.	Series.	Mark E. of N.	Mean of position.	Δ	Date, 1887.	Position.	Series.	Mark E. of N.	Mean of position.	Δ
			° ′ ″	″	″				° ′ ″	″	″
Aug. 10	I	1	4 06 15·3			Aug. 25	IX	1	4 06 13·4		
10	I	2	14·4	14·8	−2·5	25	IX	2	13·0		
10	II	1	17·2			29	IX	3	18·0	14·8	−2·5
10	II	2	16·6	16·9	−0·4	25	X	1	17·9		
11	III	1	23·3			28	X	2	18·1	18·0	+0·7
11	III	2	22·8			28	XI	1	16·2		
29	III	3	19·5			28	XI	2	17·5	16·9	−0·4
29	III	4	20·0	21·4	+4·1	28	XII	1	15·7		
13	IV	1	17·2			28	XII	2	16·8	16·3	−1·0
13	IV	2	19·3			28	XIII	1	18·2		
29	IV	3	15·7	17·4	+0·1	28	XIII	2	19·0	18·6	+1·3
13	V	1	20·2			28	XIV	1	13·9		
13	V	2	19·3			28	XIV	2	13·6		
29	V	3	19·2	19·6	+2·3	30	XIV	3	19·1	15·5	−1·8
13	VI	1	18·0			28	XV	1	19·6		
13	VI	2	20·6			29	XV	2	16·8	18·2	+0·9
29	VI	3	15·8	18·1	+0·8	29	XVI	1	16·2		
20	VII	1	14·8			29	XVI	2	17·1	16·7	−0·6
20	VII	2	17·6	16·2	−1·1	29	XVII	1	18·2		
20	VIII	1	15·9			29	XVII	2	17·7	18·0	+0·7
20	VIII	2	16·0	16·0	−1·3						

	° ′ ″ ″
Mean, of all values 4° 06′ 17″·44, and from positions	4 06 17·26 ±0·28
Mean by positions corrected for diurnal aberration	4 06 17·57
Azimuth of Mark	184 06 17·57 ±0·28
Angle between Mark and Ash Ridge	26 48 24·90
Azimuth of Ash Ridge	210 54 42·47

4. INDIANA SERIES.

(20) REIZIN, INDIANA.

$\varphi = 39° \ 02'·9$. $\lambda = 85° \ 08'·4$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour-angles.—The 50-centimetre direction theodolite No. 114 was mounted 10·241 metres from the triangulation station and accurately in line to station Tanner. The azimuth mark was at Tanner 42·6 kilometres distant. Observer, A. T. Mosman; computer, L. A. Bauer. A single result for azimuth is derived from a set of observations, consisting of 1 pointing on the mark, pointings on the star, and its image reflected from mercury, reversal of instrument, followed by similar observations of star and mark. Probable error of a single result $= \pm 0''·90$.

Summary of results for azimuth at Reizin, Indiana.

Date, 1889.	Position.	Series.	Mark E. of N.	Mean of Position.	Δ	Date, 1889.	Position.	Series.	Mark E. of N.	Mean of Position.	Δ
			° ′ ″	″	″				° ′ ″	″	″
Oct. 4	I	1	96 56 45·8			Oct. 7	VI	1	96 56 44·6		
5	I	2	46·6			7	VI	2	46·7		
5	I	3	46·8			9	VI	3	48·4	46·6	+0·7
5	I	4	45·5	46·2	+0·3	8	VII	1	46·8		
5	II	1	45·8			8	VII	2	47·1		
5	II	2	44·9			8	VII	3	47·7	47·2	+1·3
5	II	3	45·9	45·5	−0·4	8	VIII	1	43·2		
5	III	1	45·1			8	VIII	2	45·8		
5	III	2	48·5			8	VIII	3	44·6	44·5	−1·4
5	III	3	46·9	46·8	+0·9	8	IX	1	45·1		
7	IV	1	45·7			8	IX	2	46·2		
7	IV	2	47·1			8	IX	3	45·9	45·7	−0·2
7	IV	3	47·4	46·7	+0·8	9	X	1	44·0		
7	V	1	44·5			9	X	2	44·6		
7	V	2	43·0			9	X	3	45·4	44·7	−1·2
7	V	3	44·6	44·0	−1·9	9	XI	1	46·7		
						9	XI	2	47·6		
						9	XI	3	46·0	46·8	+0·9

	° ′ ″	″
Mean, of all values 45″·90, and from positions	96 56 45·88	±0·22
Diurnal aberration	+0·32	
Correction for eccentricity of station	−0·27	
Azimuth of Mark (Tanner)	276 56 45·93	±0·22

(21) WEED PATCH, INDIANA.

$\varphi = 39° \ 10'·0$. $\lambda = 86° \ 13'·0$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 30-centimetre direction theodolite No. 147 was mounted over the triangulation station. The azimuth mark was at Monroe, a State survey station, 13·5 kilometres distant. Observer, G. A. Fairfield; computer, L. A. Bauer. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, pointings on the star and its image reflected from mercury, reversal of the instrument, followed by similar observations of star and mark. Probable error of a single result = ± 2″·17.

Summary of results for azimuth at Weed Patch, Indiana.

Date, 1889.	Position.	Mark E. of N.	Mean of position.	Δ	Date, 1889.	Position.	Mark E. of N.	Mean of position.	Δ
		° ′ ″	″	″			° ′ ″	″	″
Sept. 11	I	95 23 53·5			Sept. 13	X	95 23 44·0		
18	I	49·4	51·4	+3·8	19	X	44·0	44·0	−3·6
11	II	45·0	45·0	−2·6	13	XI	48·2	48·2	+0·6
11	III	48·8	48·8	+1·2	13	XII	47·8	47·8	+0·2
11	IV	44·5	44·5	−3·1	13	XIII	42·4		
12	V	45·1	45·1	−2·5	19	XIII	44·0	43·2	−4·4
12	VI	48·6	48·6	+1·0	17	XIV	45·3	45·3	−2·3
12	VII	48·2	48·2	+0·6	17	XV	51·8		
12	VIII	51·2			19	XV	51·6	51·7	+4·1
19	VIII	46·5	48·8	+1·2	18	XVI	45·3	45·3	−2·3
13	IX	49·7	49·7	+2·1	18	XVII	52·9		
					19	XVII	53·0	52·9	+5·3

	° ′ ″	″
Mean, of all values 47″·86, and from positions	95 23 47·56	±0·51
Diurnal aberration	+0·32	
Azimuth of Mark	275 23 47·88	±0·51
Angle between Mark and Fountain	92 09 33·26	
Azimuth of Fountain	7 33 21·14	

(22) OSBORN, INDIANA.

$\varphi = 38° \; 51'.4$. $\lambda = 86° \; 52'.6$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 30-centimetre direction theodolite No. 147 was mounted over the triangulation station. The azimuth mark was in an open field, about 3 miles distant. Observer, G. A. Fairfield; computer, L. A. Bauer. A single result for azimuth is derived from a set of observations consisting of two pointings on the mark, pointings on the star and its image reflected from mercury, reversal of instrument, followed by similar pointings on star and mark. The probable error of a single result = ± 1″.00.

Summary of results for azimuth at Osborn, Indiana.

Date, 1887.	Position.	Mark W. of N.	Mean of position.	Δ	Date, 1887.	Position.	Mark W. of N.	Mean of position.	Δ
		° ′ ″	″	″			° ′ ″	″	″
June 23	I	4 14 50.4	50.4	−0.5	June 27	X	4 14 50.2	50.2	−0.7
23	II	53.1	53.1	+2.2	27	XI	(w = ½) 55.3		
26	III	(w = ½) 46.3			July 1	XI	52.1	53.2	+2.3
July 1	III	50.3	49.0	−1.9	June 27	XII	52.0	52.0	+1.1
June 26	IV	48.8	48.8	−2.1	28	XIII	49.9	49.9	−1.0
26	V	51.1	51.1	+0.2	28	XIV	51.2	51.2	+0.3
26	VI	50.5	50.5	−0.4	28	XV	51.0	51.0	+0.1
26	VII	50.6	50.6	−0.3	28	XVI	52.0	52.0	+1.1
27	VIII	53.5	53.5	+2.6	July 1	XVII	(w = ½) 44.7		
27	IX	50.1	50.1	−0.8	2	XVII	50.7	48.7	−2.2

	° ′ ″ ″
Weighted mean, of all values 50″.85, and from positions	4 14 50.90 ± 0.24
Diurnal aberration	−0.32
Azimuth of Mark	175 45 09.42 ± 0.24
Angle between Mark and Calvary	16 31 08.29
Azimuth of Calvary	192 16 17.71

5. ILLINOIS SERIES.

(23) PARKERSBURG, ILLINOIS.

$\varphi = 38° \; 34'.8$. $\lambda = 88° \; 01'.8$ West of Greenwich.

Results for azimuth from observations of 51 Cephei and α, δ, and λ Ursæ Minoris.—This azimuth was determined by A. R. Flint, of the United States Lake Survey, and a full account of it is given in "Professional Papers of the Corps of Engineers, No. 24," pages 673–686. The 35-centimetre Troughton and Simms theodolite was mounted over the triangulation station. Two azimuth marks were used. For night observations the mark was about 2 miles distant in a westerly direction. For daylight observations a mark about 11 miles to the eastward was used. A single result for azimuth is derived from a set of observations consisting of pointings on mark, star, star and mark, reversal of instrument and again pointings on mark, star, star and mark; then the same operations in the reverse order, making in all 16 pointings on the mark and the same number on the star. The star's places were taken from the American Ephemeris, but the azimuth results were corrected for the difference between the American Ephemeris and Auwers' declinations. In two cases where the number of pointings were only half the usual number, the results are given only half weight.

Summary of results for azimuth of West Azimuth Mark.

Date, 1879.	Star.	Mark W. of S.	Δ	Date, 1879.	Star.	Mark W. of S.	Δ
		° ′ ″	″			° ′ ″	″
Aug. 9	Polaris near E. E.	111 32 32·92	−0·83	Aug. 10	δ Urs. Min. near W. E.	111 32 33·24	−0·51
10	"	36·34	+2·59	11	"	34·49	+0·74
11	"	37·31	+3·58	12	"	34·64	+0·89
12	"	34·92	+1·17	13	"	35·60	+1·85
13	"	33·83	+0·08	16	"	35·50	+1·75
16	"	34·28	+0·53	17	"	31·46	−2·29
Nov. 23	Polaris near W. E.	33·05	−0·70	Nov. 20	"	35·64	+1·89
Aug. 9	51 Cephei near E. E.	(w=½) 33·89	+0·14	23	"	33·28	−0·47
11	"	35·27	+1·52	24	"	32·96	−0·79
12	"	35·17	+1·42	25	"	30·34	−3·41
13	"	34·86	+1·11	29	"	33·53	−0·22
16	"	34·21	+0·46	Aug. 12	λ Urs. Min. near W. E.	(w=½) 35·25	+1·50
17	"	31·15	−2·60	16	"	32·50	−1·25
Nov. 20	"	33·41	−0·34	17	"	31·00	−2·75
24	"	32·45	−1·30	Nov. 20	"	34·63	+0·88
25	"	31·60	−2·15	25	"	32·25	−1·50
29	"	34·41	+0·66	29	"	33·08	−0·67

	° ′ ″ ″
Weighted mean	111 32 33·75 ±0·19

Summary of results for azimuth of East Azimuth Mark.

Date, 1879.	Star.	Mark W. of S.	Δ	Date, 1879.	Star.	Mark W. of S.	Δ
		° ′ ″	″			° ′ ″	″
Aug. 11	Polaris near L. C.	290 06 28·66	−1·26	Nov. 20	Polaris near E. E.	290 06 29·88	−0·06
12	"	29·02	−0·90	21	"	29·15	−0·77
17	"	29·27	−0·65	23	"	29·81	−0·11
17	"	30·98	+1·06	24	"	51·43	+1·51
				25		31·06	+1·14

	° ′ ″ ″
Mean	290 06 29·92 ±0·36
Angle between Marks	181 26 03·51 ±0·32
Azimuth of West Mark	111 32 33·43 ±0·44
Weighted mean of results	111 32 33·70 ±0·17
Angle between West Mark and Denver	31 43 41·74
Azimuth of Denver	143 16 15·44

(24) NEWTON, ILLINOIS.

$\varphi = 38° 55'·5$. $\lambda = 88° 09'·8$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles near Eastern Elongation.—The 30-centimetre direction theodolite No. 135 was mounted over the triangulation station. The azimuth mark was at station Claremont, 23·6 kilometres distant. Observer, G. A. Fairfield; computer, L. A. Bauer. A single result for azimuth is derived from a set of observations consisting of two pointings on the mark, pointings on the star and its image reflected from mercury, followed by reversal of instrument and similar pointings on star and mark. Probable error of a single result $= \pm 1''·12$.

Summary of results for azimuth at Newton, Illinois.

Date, 1883.	Position.	Mark E. of N.	Δ	Date, 1883.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Oct. 30	I	141 29 07·2	+2·3	Nov. 2	IX	141 29 06·0	+1·1
30	II	02·3	−2·6	2	X	04·6	−0·3
31	III	04·3	−0·6	2	XI	01·6	−3·3
31	IV	07·5	+2·6	2	XII	06·0	+1·1
Nov. 1	V	02·9	−2·0	2	XIII	04·8	−0·1
1	VI	04·6	−0·3	4	XIV	06·5	+1·6
1	VII	04·7	−0·2	4	XV	06·0	+1·1
1	VIII	04·8	−0·1	6	XVI	03·1	−1·8
				6	XVII	05·7	+0·8

	° ′ ″	″
Mean	141 29 04·86	±0·27
Diurnal aberration	+0·32	
Azimuth of Claremont	321 29 05·18	

(25) BORDING, ILLINOIS.

$\varphi = 38° 36'·8$ $\lambda = 89° 20'·4$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 30-centimetre direction theodolite No. 135 was mounted over the triangulation station. The mark was at station Geoffrey, 11¾ kilometres distant. Observer, G. A. Fairfield; computer, L. A. Bauer. A single result for azimuth is derived from a set of observations consisting of two pointings on the mark, pointings on the star and its image reflected from mercury, followed by reversal of instrument and similar pointings on star and mark. Probable error of a single result = ± 1″·25.

Summary of results for azimuth at Bording, Illinois.

Date, 1882.	Position.	Mark W. of N.	Δ	Date, 1882.	Position.	Mark W. of N.	Δ
Oct. 29	II	126 34 50·86	−1·85	Nov. 6	X	126 34 50·66	−2·05
29	III	51·15	−1·56	6	XI	52·15	−0·56
Nov. 3	IV	50·05	−2·66	7	XII	52·59	−0·12
3	V	52·39	−0·32	7	XIII	52·42	−0·29
3	VI	55·28	+2·57	7	XIV	53·33	+0·62
3	VII	55·49	+2·78	7	XV	56·19	+3·48
6	VIII	50·07	−2·64	7	XVI	53·76	+1·05
6	IX	53·57	+0·86	7	XVII	53·93	+1·22
				9	I	52·26	−0·45

	° ′ ″	″
Mean	126 34 52·71	±0·30
Diurnal aberration	−0·31	
Azimuth of Geoffrey	53 25 07·60	

6. MISSOURI SERIES.

(26) KLEINSCHMIDT, MISSOURI.

$\varphi = 38° 30'·3.$ $\lambda = 90° 19'·5$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 30-centimetre repeating theodolite No. 32 was mounted over the triangulation station. The azimuth mark was about 1½ miles distant. Observer, William Eimbeck; computer, James Main. A single result for azimuth is derived from a set of observations consisting of 6 repetitions of the angle between the mark and the star, one-half with telescope direct and one-half with telescope reversed. The first set consisted of 12 repetitions, one-half

of the observations being on the star's image reflected from mercury. Probable error of a single result = $\pm 3''\cdot0$.

Summary of results for azimuth at Kleinschmidt, Missouri.

Date, 1871.	Mark E. of N.	Δ	Date, 1871.	Mark E. of N.	Δ
	° ′ ″	″		° ′ ″	″
Nov. 30	20 41 28·6	−0·8	Dec. 6	20 41 30·2	+0·8
Dec. 4	28·7	−0·7	8	29·0	−0·4
4	32·5	+3·1	11	34·6	+5·2
6	24·8	−4·6	11	36·3	+6·9
6	26·3	−3·1	11	21·5	−7·9
6	26·0	−3·4	11	31·3	+1·9
6	26·1	−3·3	11	36·4	+7·0

	° ′ ″	″
Mean	20 41 29·45	±0·79
Azimuth of Mark, corrected for diurnal aberration	200 41 29·77	±0·79
Angle between Insane Asylum and Mark	0 31 58·15	
Azimuth of Insane Asylum	200 09 31·62	

(27) BERGER, MISSOURI.

$\varphi = 38° 35'\cdot9$. $\lambda = 91° 17'\cdot5$ West of Greenwich.

Results for azimuth from observations of Polaris near Eastern Elongation.—The 35-centimetre direction theodolite was mounted over the triangulation station. The mark was a little more than a mile distant. Observer, H. W. Blair; computer, James Main. A single result for azimuth is derived from a set of observations consisting of a pointing on the mark, pointings on the star, and its image reflected from mercury, followed by reversal of the instrument and similar pointings on star and mark. Probable error of a single result = $\pm 1''\cdot51$.

Summary of results for azimuth at Berger, Missouri.

Date, 1878.	Position.	Mark W. of N.	Mean of position.	Δ	Date, 1878.	Position.	Mark W. of N.	Mean of position.	Δ
		° ′ ″	″	″			° ′ ″	″	″
Sept. 16	I	148 10 27·17			Sept. 19	IX	148 10 27·74	28·41	+0·97
16	I	26·66	26·91	−0·53	19	X	24·02		
16	II	32·65			19	X	26·37	25·20	−2·24
16	II	27·48	30·06	+2·62	20	XI	26·59		
16	III	26·20			20	XI	28·67	27·63	+0·19
16	III	25·80	26·00	−1·44	20	XII	27·63		
18	IV	26·21			20	XII	25·69	26·66	−0·78
18	IV	24·18	25·20	−2·24	21	XIII	29·24		
18	V	31·66			21	XIII	25·29	27·27	−0·17
18	V	32·80	32·23	+4·79	21	XIV	25·13		
18	VI	28·97			21	XIV	26·04	25·59	−1·85
18	VI	30·76	29·86	+2·42	21	XV	26·98		
19	VII	24·43			21	XV.	26·74	26·86	−0·58
19	VII	28·36	26·40	−1·04	25	XVI	26·38		
19	VIII	28·74			25	XVI	28·53	27·45	+0·01
19	VIII	26·72	27·73	+0·29	25	XVII	28·89		
19	IX	29·09			25	XVII	25·37	27·13	−0·31

	° ′ ″	″
Mean	148 10 27·44	±0·31
Diurnal aberration	−0·32	
Azimuth of Mark	31 49 32·88	±0·31
Angle between Mark and Winter	7 22 32·45	
Azimuth of Winter	39 12 05·33	

(28) JEFFERSON CITY, MISSOURI.

$\varphi = 38° \ 33'.7$. $\lambda = 92° \ 09'.8$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 35-centimetre direction theodolite No. 10 was mounted over the triangulation station in Jefferson City. The azimuth mark was at station Cedar, about 2·9 miles distant across the Missouri River. Observer, H. W. Blair; computers, A. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of a pointing on the mark, pointings on the star and on its image reflected from mercury, followed by reversal of instrument and similar pointings on image, star, and mark. Probable error of a single result = ± 1″·97.

Summary of results for azimuth at Jefferson City, Missouri.

Date, 1879.	Position.	Mark E. of N.	Mean of position.	Δ	Date, 1879.	Position.	Mark E. of N.	Mean of position.	Δ
		° ′ ″	″	″			° ′ ″	″	″
Nov. 15	I	19 55 32·71			Nov. 21	IX	19 55 39·22	37·72	+0·81
15	I	32·75	32·73	−4·18	21	X	35·83		
15	II	34·82			29	X	33·59	34·71	−2·20
15	II	34·78	34·80	−2·11	29	XI	36·86		
15	III	31·54			29	XI	35·04	35·95	−0·96
15	III	32·75	32·14	−4·77	29	XII	40·45		
15	IV	36·88			29	XII	40·99	40·72	+3·81
15	IV	33·38	35·13	−1·78	29	XIII	39·41		
20	V	35·81			29	XIII	38·63	39·02	+2·11
20	V	35·84	35·82	−1·09	29	XIV	35·45		
20	VI	39·58			29	XIV	35·81	35·63	−1·28
20	VI	40·94	40·26	+3·35	Dec. 1	XV	37·64		
21	VII	34·32			1	XV	39·07	38·36	+1·45
21	VII	34·14	34·23	−2·68	1	XVI	41·81		
21	VIII	38·75			1	XVI	41·56	41·68	+4·77
21	VIII	37·58	38·16	+1·25	1	XVII	41·09		
21	IX	36·22			1	XVII	39·66	40·38	+3·47

	° ′ ″ ″
Mean	19 55 36·91 ± 0·47
Diurnal aberration	+0·31
Azimuth of Cedar	199 55 37·22

(29) HUNTER, MISSOURI.

$\varphi = 38° \ 25'.8$. $\lambda = 92° \ 46'.4$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 35-centimetre direction theodolite No. 10 was mounted over the triangulation station. The mark was at North Base, 7·6 kilometres distant. Observer, F. D. Granger; computers, A. S. Christie and A. Ziwet. A single result for azimuth is obtained from a set of observations consisting of a pointing on the mark, pointings on the star, and its image reflected from mercury, then reversal of instrument and similar pointings on star, reflected image and mark. Probable error of a single result = ± 1″·83.

Summary of results for azimuth at Hunter, Missouri.

Date, 1880.	Position.	Mark W. of N.	Mean of position.	Δ	Date, 1880.	Position.	Mark W. of N.	Mean of position.	Δ
		° ′ ″	″	″			° ′ ″	″	″
Aug. 6	I	22 09 24·73			Aug. 9	IX	22 09 22·83		
6	I	24·68	24·70	+0·60	9	IX	21·92	22·38	−1·72
6	II	17·08			11	X	19·81		
6	II	19·96			11	X	22·73	21·27	−2·83
12	II	21·48			11	XI	27·28		
12	II	21·25	19·94	−4·16	11	XI	26·05	26·66	+2·56
6	III	25·34			11	XII	24·94		
6	III	25·75	25·54	+1·44	11	XII	24·42	24·68	+0·58
7	IV	25·35			11	XIII	24·18		
7	IV	25·43	25·39	+1·29	11	XIII	25·48	24·83	+0·73
7	V	29·86			12	XIV	21·80		
7	V	28·92	29·39	+5·29	12	XIV	25·72	23·76	−0·34
9	VI	24·11			12	XV	22·32		
9	VI	23·12	23·62	−0·48	12	XV	25·17	23·74	−0·36
9	VII	20·95			12	XVI	26·44		
9	VII	23·25	22·10	−2·00	12	XVI	23·04	24·74	+0·64
9	VIII	21·07			12	XVII	24·35		
9	VIII	22·39	21·73	−2·37	12	XVII	26·13	25·24	+1·14

	° ′	″	″
Mean by positions	22 09	24·10	±0·36
Diurnal aberration		−0·32	
Azimuth of Mark	157 50	36·22	±0·36
Angle between Mark and Christian	63 57	44·40	
Azimuth of Christian	221 48	20·62	

7. MISSOURI–KANSAS SERIES.

(30) ADAMS, KANSAS.

$\varphi = 39° \; 02'{\cdot}7$. $\lambda = 96° \; 04'{\cdot}4$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 35-centimetre direction theodolite No. 10 was mounted over the triangulation station. The azimuth mark was at Buffalo Mound, about 2 kilometres distant. Observer, F. D. Granger; computer, L. A. Bauer. A single result for azimuth is derived from a set of observations consisting of a pointing on the mark, pointings on the star, and its image reflected from mercury, then reversal of the instrument and similar pointings on star, reflected image and mark. Probable error of a single result = $\pm 0''{\cdot}80$.

Summary of results for azimuth at Adams, Kansas.

Date, 1888.	Position.	Mark W. of N.	Mean of position.	Δ	Date, 1888.	Position.	Mark W. of N.	Mean of position.	Δ
		° ′ ″	″	″			° ′ ″	″	″
July 18	I	0 11 28·4			July 20	IX	0 11 28·1		
18	I	27·2	27·8	−0·3	20	IX	28·0	28·1	0·0
18	II	30·2			21	X	29·6		
18	II	26·0	28·1	0·0	21	X	28·2	28·9	+0·8
19	III	28·8			21	XI	27·8		
19	III	29·2			21	XI	27·9	27·9	−0·2
22	III	28·2	28·7	+0·6	21	XII	26·8		
19	IV	26·9			21	XII	27·0	26·9	−1·2
19	IV	25·7	26·3	−1·8	21	XIII	29·0		
19	V	28·0			21	XIII	25·8	27·4	−0·7
19	V	27·7	27·8	−0·3	22	XIV	25·8		
20	VI	30·3			22	XIV	27·9	26·9	−1·2
20	VI	28·3	29·3	+1·2	22	XV	29·4		
20	VII	28·8			22	XV	27·6	28·5	+0·4
20	VII	27·9	28·4	+0·3	22	XVI	28·8		
20	VIII	27·7			22	XVI	29·7	29·2	+1·1
20	VIII	29·5	28·6	+0·5	22	XVII	28·6		
					22	XVII	27·9	28·2	+0·1

	° ′ ″ ″
Mean by positions	0 11 28·06 ± 0·14
Diurnal aberration	−0·32
Azimuth of Mark	179 48 32·26 ± 0·14
Angle between Mark and Clark	191 57 39·67
Azimuth of Clark	11 46 11·93

(31) SALINA WEST BASE, KANSAS.

$\varphi = 38° 51'·1$. $\lambda = 97° 36'·2$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles near Eastern Elongation.—The 30-centimetre direction theodolite No. 118 was mounted over the triangulation station at the west end of the Salina Base. The mark was at Salina East Base, distant 6·5 kilometres. Observer, F. D. Granger; computer, C. H. Kummell. A single result for azimuth is derived from a set of observations consisting of a pointing on the mark, pointings on the star, and its image reflected from mercury, then reversal of instrument and similar pointings on star, reflected image and mark. Probable error of a single result = ±1″·08.

Summary of results for azimuth at Salina West Base, Kansas.

Date, 1896.	Position.	Azimuth of mark.	Δ	Date, 1896.	Position.	Azimuth of mark.	Δ
		° ′ ″	″			° ′ ″	″
Aug. 3	I	248 36 20·4	+2·6	Aug. 4	VII	248 36 14·4	−3·4
3	I	19·9	+2·1	4	VII	16·1	−1·7
3	II	20·3	+2·5	4	VIII	18·8	+1·0
3	II	19·5	+1·7	6	VIII	16·6	−1·2
3	III	16·8	−1·0	4	IX	16·9	−0·9
3	III	17·5	−0·3	4	IX	14·9	−2·9
3	IV	18·7	+0·9	6	IX	19·1	+1·3
3	IV	18·0	+0·2	6	IX	16·8	−1·0
5	V	17·2	−0·6	4	X	15·9	−1·9
3	V	18·7	+0·9	4	X	17·6	−0·2
4	VI	18·5	+0·7	4	XI	15·9	−1·9
4	VI	18·0	+0·2	6		19·8	+2·0

	° ′ ″ ″
Indiscriminate mean	248 36 17·76 ± 0·22.
Diurnal aberration	+0·32.
Azimuth of Salina East Base	248 36 18·08.

8. KANSAS-COLORADO SERIES.

(32) RUSSELL SOUTHEAST, KANSAS.

$\varphi = 38° 51'.4$. $\lambda = 98° 47'.2$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles not far from Eastern Elongation.—The 35-centimetre direction theodolite No. 10 was mounted over the triangulation station. The mark was at Russell Northwest, about 3·3 miles distant. Observers, F. D. Granger and H. L. Stidham; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of a pointing on the mark, pointings on the star, and its image reflected from mercury, reversal of instrument, followed by pointings on star, image, and mark. Probable error of a single result $= \pm 0''.89$.

Summary of results for azimuth at Russell Southeast, Kansas.

Date, 1893.	Position.	Mark W. of N.	Mean of position.	△	Date, 1893.	Position.	Mark W. of N.	Mean of position.	△
		° ′ ″	″	″			° ′ ″	″	″
Oct. 2	I	39 16 61·09			Oct. 4	IX	39 16 60·75	60·48	−0·15
7	I	58·22	59·66	−0·97	4	X	61·81		
2	II	60·50			4	X	59·08	60·44	−0·19
7	II	60·06	60·28	−0·35	4	XI	59·58		
3	III	60·63			4	XI	59·90	59·74	−0·89
3	III	62·30	61·46	+0·83	5	XII	59·11		
3	IV	61·16			5	XII	60·54	59·82	−0·81
3	IV	59·17	60·16	−0·47	5	XIII	58·70		
3	V	62·63			6	XIII	62·62	60·66	+0·03
3	V	62·88	62·76	+2·13	6	XIV	60·19		
3	VI	58·43			6	XIV	61·10	60·64	+0·01
3	VI	59·36	58·90	−1·73	6	XV	60·37		
3	VII	61·26			6	XV	59·57	59·97	−0·66
4	VII	61·61	61·44	+0·81	6	XVI	62·65		
4	VIII	61·08			6	XVI	63·08	62·86	+2·23
4	VIII	60·51	60·80	+0·17	8	XVII	61·54		
4	IX	60·21			8	XVII	59·79	60·66	+0·03

	° ′ ″ ″
Mean, Mark West of North	39 16 60·63 ± 0·15
Diurnal aberration	−0·32
Azimuth of Russell Northwest	140 42 59·69 ± 0·15

(33) OVERLAND, COLORADO.

$\varphi = 39° 02'.3$. λ 103° 09′·8 West of Greenwich.

Results for azimuth from observations of δ Ursæ Minoris at Upper Culmination, 51 Cephei at Lower Culmination and λ Ursæ Minoris at Upper Culmination.—Meridian telescope No. 9 was mounted on a wooden pier 4·44 metres north of the triangulation station and exactly in line with the azimuth mark, which was about a mile distant. The angle between mark and star at culmination was measured by means of the eye-piece micrometer. Observer, O. H. Tittmann; computer, L. A. Bauer. A single result for azimuth is derived from a set of observations consisting generally of 20 readings of the mark, with reversal of the telescope in the middle, followed by 11 readings of the star. In observing λ Ursæ Minoris the telescope was reversed also during the star observations and the mark readings were repeated at the close of the set. Probable error of a single result $= \pm 1''.26$.

Summary of results for azimuth at Overland, Colorado.

Date, 1881.	Star.	Phase.	Mark W. of N.	Δ	Date, 1881.	Star.	Phase.	Mark W of N.	Δ
			″	″				″	″
Sept. 15	δ Urs. Min.	U. C.	5·67	+0·44	Sept. 19	δ Urs. Min.	U. C.	5·98	+0·75
15	51 Cephei	L. C.	8·17	+2·94	19	51 Cephei	L. C.	6·69	+1·46
16	δ Urs. Min.	U. C.	1·83	−3·40	21	δ Urs. Min.	U. C.	3·17	−2·06
16	51 Cephei	L. C.	3·67	−1·56	21	51 Cephei	L. C.	4·97	−0·26
16	λ Urs. Min.	U. C.	6·38	+1·15	21	λ Urs. Min.	U. C.	5·78	+0·55

	° ′ ″	″
Mean	5·23	±0·40
Diurnal aberration	−0·32	
Azimuth of Mark	179 59 55·09	±0·40
Angle between Mark and Eureka	104 10 37·64	
Azimuth of Eureka	284 10 32·73	

(34) EL PASO EAST BASE, COLORADO.

$\varphi = 38° 57'\cdot3$. $\lambda = 104° 27'\cdot2$ West of Greenwich.

Results for azimuth from observations of λ Ursæ Minoris and α Ursæ Minoris at Upper Culmination and δ Ursæ Minoris at Lower Culmination.—Meridian telescope No. 3 was mounted 4·76 metres south of the East end of the El Paso Base Line in the prolongation of the line to the mark. The azimuth mark was about 3 miles distant. Observer, O. H. Tittmann; computers, A. S. Christie and J. G. Porter. The angle between mark and star was measured by means of the eyepiece micrometer. A single result for azimuth is derived from a set of observations consisting of 10 readings of the mark, 10 bisections of the star taken at equal intervals of time, reversal of telescope, 10 more bisections of star, and 10 more readings of mark. Probable error of a single result at Upper Culmination = ±0″·83. On account of the small number of observations the single result for Lower Culmination is retained, but is given less weight.

Summary of results for azimuth at El Paso East Base, Colorado.

Date, 1879.	Star.	Phase.	Mark E. of N.	Δ	
			″	″	
Oct. 5	λ Urs. Min.	U. C.	2·84	+0·23	
6	λ Urs. Min.	U. C.	4·31	+1·70	
8	δ Urs. Min.	L. C.	9·76	+7·15	W=⅓
10	α Urs. Min.	U. C.	2·20	−0·41	
11	α Urs. Min.	U. C.	0·53	−2·08	
13	α Urs. Min.	U. C.	1·65	−0·96	
16	α Urs. Min.	U. C.	1·75	−0·86	

	° ′ ″	″
Weighted mean	2·61	±0·59
Diurnal aberration	+0·32	
Azimuth of Mark	180 00 02·93	±0·59
Angle between Mark and El Paso West Base	282 48 01·48	
Azimuth of El Paso West Base	102 48 04·41	

9. ROCKY MOUNTAIN SERIES.

(35) PIKES PEAK, COLORADO.

$\varphi = 38° 50'·4$. $\lambda = 105° 02'·7$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted $2\frac{5}{16}$ inches south of the triangulation station. The mark was at Mount Rosa, 12·72 kilometres distant. Observer, R. L. Faris; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ±0″·91.

Summary of results for azimuth at Pikes Peak, Colorado.

Hour angle of star 7^h to 10^h.				Hour angle of star 14^h to 17^h.			
Date, 1895.	Position.	Mark E. of N.	v	Date, 1895.	Position.	Mark E. of N.	v
		° ′ ″	″			° ′ ″	″
Oct. 1	I	138 53 37·20	−2·18	Oct. 6	V	138 53 39·04	0·34
4	III	39·84	+0·46	6	VI	37·41	−1·97
4	IV	42·19	+2·81	6	VII	39·82	+0·44
6	IX	39·31	−0·07	6	VIII	39·90	+0·52
6	X	37·75	1·63	8	XV	39·82	+0·44
6	XI	38·63	−0·75	8	XVI	39·43	+0·05
7	XII	38·06	1·32	8	XVII	39·12	−0·26
7	XIII	40·16	+0·78	8	I	40·75	+1·37
7	XIV	[43·39]	Rejected		Mean	138 53 39·41	
8	II	38·71	−0·67				
8	IV	41·77	+2·39				
	Mean	138 53 39·36					

	° ′ ″	″
Mean of groups	138 53 39·38	±0·22
Diurnal aberration	+0·32	
Reduction to center of station	+0·64	
Azimuth of Mark	318 53 40·34	±0·22
Angle between Mark and Mount Ouray	107 11 36·41	
Azimuth of Mount Ouray	66 05 16·75	

(36) MOUNT OURAY, COLORADO.

$\varphi = 38° 25'·3$. $\lambda = 106° 13'·6$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was about 5 miles distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ±0″·61 for star near Upper Culmination and ±0″·58 near Lower Culmination.

Summary of results for azimuth at Mount Ouray, Colorado.

Near Upper Culmination.				Near Lower Culmination.			
Date, 1894.	Position.	Mark W. of N.	Δ	Date, 1894.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
July 25	XIV	178 12 [47·83]	Rejected	July 25	VI	178 12 48·63	−1·95
25	XV	53·19	+2·61	26	XI	48·49	−2·09
25	XVI	52·90	+2·32	27	I	49·33	−1·25
26	XII	52·15	+1·57	27	II	51·02	+0·44
26	XIII	50·91	+0·33	27	VI	48·60	−1·98
26	XVII	52·37	+1·79	27	VII	49·20	−1·38
27	III	50·64	+0·06	28	VIII	49·67	−0·91
27	IV	52·50	+1·92	28	IX	48·31	−2·27
27	V	51·85	+1·27	28	X	48·58	−2·00
	Mean	178 12 52·06			Mean	178 12 49·09	

	° ′ ″ ″
Mean of groups	178 12 50·58 ± 0·29
Diurnal aberration	−0·32
Azimuth of Mark	1 47 09·74 ± 0·29
Angle between Mark and Uncompahgre	68 48 41·61
Azimuth of Uncompahgre	70 35 51·35

(37) GUNNISON, COLORADO.

$\varphi = 38° 32'·7$. $\lambda = 106° 55'·5$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The mark was about 2 miles distant. Observer, John Nelson; computer, D. L. Hazard. A single result is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ±0″·87.

Summary of results for azimuth at Gunnison, Colorado.

Hour angle of star 6^h to 8^h.				Hour angle of star 15^h to 17^h.			
Date, 1893.	Position.	Mark E. of N.		Date, 1893.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Oct. 4	I	147 45 06·55	+1·54	Oct. 5	III	147 45 02·85	−2·16
4	II	[01·73]	Rejected	5	[illegible]	03·10	−1·91
5	VI	03·82	−1·19	5	V	05·87	+0·86
5	VII	06·27	+1·26	6	X	06·95	+1·94
5	VIII	04·50	−0·51	6	XI	[09·91]	Rejected
5	IX	03·54	−1·47	6	XII	05·39	+0·38
6	XIV	05·19	+0·18	6	XIII	05·85	+0·84
6	XV	05·26	+0·25	7	XVII	05·95	+0·94
6	XVI	04·63	−0·38	7	XVIII	03·52	−1·49
	Mean	147 45 04·97		7	XIX	04·32	−0·69
				7	XI	06·70	+1·69
					Mean	147 45 05·05	

	° ′ ″ ″
Mean of groups	147 45 05·01 ± 0·20
Diurnal aberration	+0·32
Azimuth of Mark	327 45 05·33 ± 0·20
Angle between Mark and Uncompahgre	74 09 54·99
Azimuth of Uncompahgre	41 55 00·32

(38) TREASURY MOUNTAIN, COLORADO.

$\varphi = 39° 00'.8$. $\lambda = 107° 06'.0$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was 1·7 miles distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ± 0″·59.

Summary of results for azimuth at Treasury Mountain, Colorado.

Hour angle of star 15^h to 17^h.				Hour angle of star 5^h to 7^h.			
Date, 1893.	Position.	Mark W. of N.	Δ	Date, 1893.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Sept. 21	I	58 55 02·59	+0·23	Sept. 21	IV	58 55 02·85	+0·49
21	II	03·13	+0·77	21	V	02·22	−0·14
21	III	01·70	−0·66	21	VI	03·03	+0·67
22	VII	02·96	+0·60	22	X	01·42	−0·94
22	VIII	03·23	+0·87	22	XI	01·99	−0·37
22	IX	02·40	+0·04	22	XII	02·80	+0·44
23	XIII	03·01	+0·65	23	XVI	01·84	−0·52
23	XIV	00·71	−1·65	23	XVII	02·50	+0·14
23	XV	01·60	−0·76	23	XVIII	01·72	−0·64
24	XIX	02·30	−0·06	24	XXII	01·01	−1·35
24	XX	04·29	+1·93	24	XXIII	01·22	−1·14
24	XXI	03·91	+1·55	24	XIX	02·23	−0·13
	Mean	58 55 02·65			Mean	58 55 02·07	

	° ′ ″	″
Mean of groups	58 55 02·36	± 0·12
Diurnal aberration	−0·32	
Azimuth of Mark	121 04 57·96	± 0·12
Angle between Mount Waas and Mark	46 19 53·32	
Azimuth of Mount Waas	74 45 04·64	

(39) UNCOMPAHGRE, COLORADO.

$\varphi = 38° 04'.3$. $\lambda = 107° 27'.8$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was 2·8 miles distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ± 0″·77.

Summary of results for azimuth at Uncompahgre, Colorado.

Hour angle of star 5^h to 8^h.				Hour angle of star 14^h to 16^h.			
Date, 1895.	Position.	Mark W. of N.	Δ	Date, 1895.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Sept. 3	XI	105 50 59·56	−0·67	Sept. 1	IV	105 50 61·55	+1·32
3	XII	58·92	−1·31	2	VII	60·20	−0·03
4	XVII	59·74	−0·49	4	XIII	58·56	−1·67
4	I	59·42	−0·81	4	XIV	60·94	+0·71
4	II	61·39	+1·16	4	XV	60·10	−0·13
5	VI	62·25	+2·02	5	III	61·54	+1·31
5	VIII	59·44	−0·79	5	IV	61·27	+1·04
5	IX	58·16	−2·07	5	V	61·09	+0·86
6	XIII	59·66	−0·57	6	X	59·75	−0·48
				6	XVI	61·23	+1·00
	Mean	105 50 59·84			Mean	105 50 60·62	

	° ′ ″	″
Mean of groups	105 50 60·23	±0·18
Diurnal aberration	−0·32	
Azimuth of Mark	74 09 00·09	±0·18
Angle between Mark and Treasury Mountain	122 33 55·75	
Azimuth of Treasury Mountain	196 42 55·84	

(40) GRAND JUNCTION, COLORADO.

$\varphi = 39° 04'·0$. $\lambda = 108° 33'·9$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The mark was at Chiquita, 19·6 kilometres distant. Observer, John Nelson; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result $= \pm 1''·83$.

Summary of results for azimuth at Grand Junction, Colorado.

Hour angle of star 8^h to 11^h.				Hour angle of star 21^h to 24^h.			
Date, 1895.	Position.	Mark W. of N.	Δ	Date, 1895.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
June 4	II	156 02 35·35	−0·94	June 3	I	156 02 33·96	−2·33
4	III	34·59	−1·70	4	IV	38·66	+2·37
5	IV	36·25	−0·04	5	VI	31·94	−4·35
5	V	43·40	+7·11	5	VII	36·93	+0·64
6	VIII	34·39	−1·90	6	X	38·28	+1·99
6	IX	37·16	+0·87	6	XI	35·50	−0·79
	Mean	156 02 36·86		7	I	36·75	+0·46
				7	II	34·87	−1·42
					Mean	156 02 35·86	

	° ′ ″	″
Mean of all	156 02 36·29	±0·49
Diurnal aberration	−0·32	
Azimuth of Chiquita	23 57 24·03	±0·49

(41) TAVAPUTS, COLORADO.

$\varphi = 39° 32'.3$. $\lambda = 109° 00'.4$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The mark was about 3 miles distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument and similar pointings on star and mark. Probable error of a single result = ±0″.84.

Summary of results for azimuth at Tavaputs, Colorado.

Near Eastern Elongation.				Near Western Elongation.			
Date, 1891.	Position.	Mark E. of N.	Δ	Date, 1891.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Oct. 12	I	21 39 08.11	−1.79	Oct. 12	IV	21 39 11.72	+1.82
12	II	09.02	−0.88	12	V	12.00	+2.10
12	III	10.12	+0.22	13	IX	11.06	+1.16
13	VI	08.52	−1.38	13	X	08.96	−0.94
13	VII	08.70	−1.20	13	XI	09.77	−0.13
13	VIII	09.29	−0.61	14	XV	12.41	+2.51
14	XII	11.21	+1.31	14	XVI	10.93	+1.03
14	XIII	10.01	+0.11	14	XVII	09.68	−0.22
14	XIV	09.94	+0.04	15	XVIII	07.76	−2.14
16	XXI	10.02	+0.12	15	XIX	10.55	+0.65
16	XXII	09.38	−0.52	15	XX	08.41	−1.49
16	XXIII	11.32	+1.42	16	VI	09.00	−0.90
16	I	10.82	+0.92	16	XV	08.36	−1.54
				16	VIII	10.41	+0.51
	Mean	21 39 09.73			Mean	21 39 10.07	

	° ′ ″	″
Mean of groups	21 39 09.90	±0.16
Diurnal aberration	+0.32	
Azimuth of Mark	201 39 10.22	±0.16
Angle between Patmos Head and Mark	113 21 29.64	
Azimuth of Patmos Head	88 17 40.58	

(42) MOUNT WAAS, UTAH.

$\varphi = 38° 32'.5$. $\lambda = 109° 13'.7$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was about 7.1 miles distant. Observers, W. Eimbeck and J. Nelson; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ±0″.90.

Summary of results for azimuth at Mount Waas, Utah.

Near Upper Culmination.				Near Lower Culmination.			
Date, 1893.	Position.	Mark W. of N.	Δ	Date, 1893.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Aug. 1	I	165 49 15·98	−1·65	Aug. 4	XI	165 49 16·81	−0·82
1	II	19·60	+1·97	4	XVIII	18·52	+0·89
2	III	16·92	−0·71	6	XIV	18·83	+1·20
2	IV	16·84	−0·79	6	XV	19·04	+1·41
2	V	16·41	−1·22		Mean	165 49 18·30	
2	VI	16·92	−0·71				
3	VII	17·23	−0·40				
3	VIII	16·32	−1·31				
3	IX	16·91	−0·72				
3	X	19·36	+1·73				
4	XII	16·23	−1·40				
4	XIII	17·43	−0·20				
	Mean	165 49 17·18					

	° ′ ″ ″
Mean of groups giving weights 3 and 2,	165 49 17·63 ±0·20
Diurnal aberration	−0·32
Azimuth of Mark	14 10 42·69 ±0·20
Angle between Mark and Mount Ellen	57 49 33·98
Azimuth of Mount Ellen	72 00 16·67

(43) PATMOS HEAD, UTAH.

$\varphi = 39°\ 29'.9$. $\lambda = 110°\ 19'.0$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was about a mile distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = $\pm 0''.71$.

Summary of results for azimuth at Patmos Head, Utah.

Before Lower Culmination.				After Lower Culmination.			
Date, 1890.	Position.	Mark of W. of N.	Δ	Date, 1890.	Position.	Mark W. of N.	Δ
		° ′ ″				° ′ ″	
Oct. 15	XII	11 14 28·77	+0·25	Oct. 16	XIII	11 14 28·27	−0·25
16	I	26·85	−1·67	16	XIV	30·06	+1·54
16	II	30·21	+1·69	17	V	28·38	−0·14
16	III	28·88	+0·36	17	VI	29·36	+0·84
16	IV	28·94	+0·42	18	IX	27·44	−1·08
17	XXII	27·85	−0·67	18	X	29·07	+0·55
17	XXIII	30·51	+1·99	18	XI	27·23	−1·29
17	VII	28·27	−0·25	18	XV	29·54	+1·02
17	VIII	27·87	−0·65	19	XX	28·12	−0·40
18	XVI	27·81	−0·71	20	I	26·73	−1·79
18	XVII	27·79	−0·73	20	XII	29·73	+1·21
18	XVIII	28·44	−0·08	20	X	27·86	−0·66
18	XIX	29·97	+1·45		Mean	11 14 28·49	
19	XXI	27·44	−1·08				
	Mean	11 14 28·54					

	° ′ ″ ″
Mean of groups	11 14 28·52 ±0·14
Diurnal aberration	−0·32
Azimuth of Mark	168 45 31·80 ±0·14
Angle between Wasatch and Mark	102 04 13·12
Azimuth of Wasatch	66 41 18·68

(44) MOUNT ELLEN, UTAH.

$\varphi = 38° 07'.4$. $\lambda = 110° 48'.9$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The mark was about 2 miles distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ± 0″·64.

Summary of results for azimuth at Mount Ellen, Utah.

Date, 1891.	Position.	Mark E. of N.	Δ	Date, 1891.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Aug. 18	XII	162 18 07·24	+1·35	Aug. 22	VII	162 18 06·11	+0·22
18	XIII	05·35	−0·54	23	VIII	06·74	+0·85
18	XIV	05·87	−0·02	23	IX	06·67	+0·78
18	XV	05·60	−0·29	23	X	03·61	−2·28
19	XVI	06·21	+0·32	23	XI	05·02	−0·87
19	XVII	05·24	−0·65	23	XII	06·85	+0·96
19	XVIII	06·32	+0·43	23	XX	05·91	+0·02
19	XIX	05·82	−0·07	24	VIII	06·58	+0·69
20	III	05·35	−0·54	24	XXI	05·26	−0·63
20	IV	05·11	−0·78	24	XXII	04·99	−0·90
20	V	06·41	+0·52	24	XXIII	04·17	−1·72
21	II	08·17	+2·28	25	XIX	05·61	−0·28
22	I	07·39	+1·50	25	XX	05·70	−0·19
22	VI	05·65	−0·24	25	II	06·04	+0·15

	° ′ ″ ″
Mean of all	162 18 05·89 ±0·12
Diurnal aberration	+0·32
Azimuth of Mark	342 18 06·21 ±0·12
Angle between Patmos Head and Mark	146 42 08·60
Azimuth of Patmos Head	195 35 57·61

(45) WASATCH, UTAH.

$\varphi = 39° 06'·9.$ $\gamma = 111° 27'·2$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was at Baldy Peak, about 4 miles distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result $= \pm 0''·55$.

Summary of results for azimuth at Wasatch, Utah.

Hour angle 2^h to 5^h.				Hour angle 12^h to 15^h.			
Date, 1890.	Position.	Mark W. of N.	Δ	Date, 1890.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Aug 20	IV	75 21 19·84	+0·83	Aug. 20	I	75 21 19·85	+0·84
20	V	17·21	−1·80	20	II	20·60	+1·59
20	VI	19·29	+0·28	20	III	18·68	−0·33
20	VII	19·05	+0·04	22	VIII	18·78	−0·23
22	X	19·03	+0·02	22	IX	18·97	−0·04
22	XI	19·77	+0·76	23	XIV	20·43	+1·42
22	XII	18·78	−0·23	23	XV	19·60	+0·59
22	XIII	18·02	−0·99	23	XVI	17·62	−1·39
23	XVIII	18·64	−0·37	23	XVII	18·24	−0·77
23	XIX	19·02	+0·01	24	XXII	19·02	+0·01
23	XX	18·31	−0·70	24	XXIII	19·75	+0·74
23	XXI	17·89	−1·12	24	XXIII	19·30	+0·29
24	I	18·66	−0·35	25	XIV	18·94	−0·07
24	XV	19·78	+0·77				
	Mean	75 21 18·81			Mean	75 21 19·21	

	° ′ ″	″
Mean of groups	75 21 19·01	±0·11
Diurnal aberration	·0·32	
Azimuth of Mark	104 38 41·31	±0·11
Angle between Mark and Mount Nebo	56 15 21·17	
Azimuth of Mount Nebo	160 54 02·48	

(46) MOUNT NEBO, UTAH.

$\varphi = 39° 48'·5.$ $\lambda = 111° 46'·0$ West of Greenwich.

Results for azimuth from observations of Polaris near Upper and Lower Culminations.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was about 5 miles distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result $= \pm 0''·46$.

Summary of results for azimuth at Mount Nebo, Utah.

Near Upper Culmination.				Near Lower Culmination.			
Date, 1887.	Position.	Mark E. of N.	Δ	Date, 1887.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
July 20	III	5 28 43·24	+0·74	July 20	I	5 28 42·98	+0·48
20	IV	43·50	+1·00	20	II	43·57	+1·07
20	V	42·47	−0·03	21	VIII	42·33	−0·17
20	VI	41·93	−0·57	21	IX	43·15	+0·65
20	VII	41·77	−0·73	21	X	41·92	−0·58
21	XI	42·41	−0·09	22	XVII	42·21	−0·29
21	XII	42·97	+0·47	22	XVIII	43·02	+0·52
21	XIII	41·55	−0·95	22	XIX	42·20	−0·30
21	XIV	41·63	−0·87	22	XX	42·38	−0·12
21	XV	42·78	+0·28	22	XXI	42·00	−0·50
21	XVI	44·08	+1·58	23	I	42·45	−0·05
22	XXI	42·08	−0·42	23	III	41·31	−1·19
22	XXII	42·97	+0·47		Mean	5 28 42·46	
22	XXIII	42·11	−0·39				
	Mean	5 28 42·54					

	° ′ ″ ″
Mean of groups	5 28 42·50 ± 0·09
Diurnal aberration	+0·32
Azimuth of Mark	185 28 42·82 ± 0·09
Angle between Mark and Tushar	194 36 40·39
Azimuth of Tushar	20 05 23·21

(47) SALT LAKE CITY, UTAH.

$\varphi = 40^\circ\ 46'\cdot1$. $\lambda = 111^\circ\ 53'\cdot5$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre theodolite No. 5 was mounted over the triangulation station in Temple Block, Salt Lake City. The azimuth mark was at City Creek station, about 4·3 kilometres distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = $\pm 0''\cdot64$.

Summary of results for azimuth at Salt Lake City, Utah.

Hour angle of star 9^h to 11^h.				Hour angle of star 21^h to 23^h.			
Date, 1893.	Position.	Mark E. of N.	Δ	Date, 1893.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
June 2	I	12 02 50·29	−0·08	June 3	III	12 02 49·74	−0·63
3	I	51·19	+0·82	3	IV	51·55	+1·18
3	II	48·68	−1·69	4	VII	51·00	+0·63
4	V	50·02	−0·35	4	VIII	50·40	+0·03
4	VI	49·59	−0·78	4	IX	50·32	−0·05
5	X	49·34	−1·03	5	XIII	50·35	−0·02
5	XI	50·34	−0·03	5	XIV	50·80	+0·43
5	XII	50·58	+0·21	5	XV	50·44	+0·07
6	XVII	52·33	+1·96	5	XVI	50·94	+0·57
6	XVIII	51·79	+1·42	6	XX	51·93	+1·56
6	XIX	49·64	−0·73	6	XXI	49·90	−0·47
7	XXIII	49·00	−1·37	6	XXII	48·75	−1·62
7	XIII	50·28	−0·09		Mean	12 02 50·51	
	Mean	12 02 50·24					

	° ′ ″ ″
Mean of groups	12 02 50·37 ± 0·13
Diurnal aberration	+0·32
Azimuth of Mark (City Creek)	192 02 50·69 ± 0·13

(48) WADDOUP, UTAH.

$\varphi = 40° 54'.4$. $\lambda = 111° 53'.2$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite was mounted over the triangulation station. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ± 0''.98.

Summary of results for azimuth at Waddoup, Utah.

Near Upper Culmination.				Near Lower Culmination.			
Date, 1892.	Position.	Mark E. of N.	Δ	Date, 1892.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
June 13	IV	149 14 06.26	+0.24	June 13	I	149 14 06.60	+0.58
13	VIII	08.03	+2.01	16	XIV	03.27	−2.75
14	XII	07.32	+1.30	17	XX	06.79	+0.77
14	XVI	05.04	−0.98	17	XXIII	04.98	−1.04
				17	III	05.28	−0.74
	Mean	149 14 06.66			Mean	149 14 05.38	

	° ′ ″	″
Mean of groups	149 14 06.02	± 0.33
Diurnal aberration	+ 0.32	
Azimuth of Mark	329 14 06.34	± 0.33
Angle between Ogden Peak and Mark	148 31 33.66	
Azimuth of Ogden Peak	180 42 32.68	

(49) OGDEN OBSERVATORY, UTAH.

$\varphi = 41° 13'.1$. $\lambda = 111° 59'.7$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite was mounted over the triangulation station, about 4 metres south of the longitude pier in the United States Engineers' Observatory at Ogden. The azimuth mark was at North Ogden Peak, about 10 miles distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ± 0''.45.

Summary of results for azimuth at Ogden Observatory, Utah.

Hour angle of star 9^h to 11^h.				Hour angle of star 20^h to 24^h.			
Date, 1891.	Position.	Mark E. of N.	Δ	Date, 1891.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
May 27	I	10 03 56·47	−0·49	June 3	IV	10 03 56·45	−0·51
30	I	56·43	−0·53	3	V	57·24	+0·28
30	II	56·77	−0·19	3	VI	57·05	+0·09
30	III	57·32	+0·36	4	X	56·00	−0·96
June 4	VII	57·46	+0·50	4	XI	57·23	+0·27
4	VIII	58·74	+1·78	4	XII	57·83	+0·87
4	IX	56·70	−0·26	5	XVI	56·37	−0·59
5	XIII	56·64	−0·32	5	XVII	56·82	−0·14
5	XIV	56·06	−0·90	5	XVIII	57·24	+0·28
5	XV	57·57	+0·61	9	XXIII	56·91	−0·05
6	XIX	57·09	+0·13	9	XXIII	57·19	+0·23
7	XX	56·07	−0·89	9	IX	57·75	+0·79
7	XXI	55·97	−0·99		Mean	10 03 57·01	
7	XXII	57·66	+0·70				
	Mean	10 03 56·92					

	° ′ ″	″
Mean of groups	10 03 56·96	±0·09
Diurnal aberration	+0·32	
Azimuth of Mark	190 03 57·28	±0·09
Angle between Mark and Ogden Peak	93 04 47·35	
Azimuth of Ogden Peak	283 08 44·63	

(50) OGDEN PEAK, UTAH.

$\varphi = 41° 12'{\cdot}0$. $\lambda = 111° 53'{\cdot}0$ West of Greenwich.

Results for azimuth from observations of Polaris near Eastern and Western Elongations.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The mark was at North Ogden Peak, about 10 miles distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result $= \pm 0''{\cdot}73$.

Summary of results for azimuth at Ogden Peak, Utah.

Near Eastern Elongation.				Near Western Elongation.			
Date, 1888.	Position.	Mark W. of N.	Δ	Date, 1888.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Sept. 30	I	19 56 58·66	−2·01	Oct. 3	IV	19 56 60·00	−0·67
Oct. 2	II	61·02	+0·35	3	V	[56·67]	Rejected
2	II	61·57	+0·90	3	VI	60·11	−0·56
4	VIII	[54·29]	Rejected	3	VII	60·13	−0·54
5	IX	60·19	−0·48	5	XIV	61·68	+1·01
5	X	62·16	+1·49	5	XV	60·01	−0·66
5	XI	60·39	−0·28	5	XVI	58·91	−1·76
5	XII	60·25	−0·42	5	XVII	58·94	−1·73
5	XIII	[67·56]	Rejected	5	XVIII	60·47	−0·20
6	XIX	62·83	+2·16	7	XXII	60·08	−0·59
6	XX	61·34	+0·67	7	XXII	60·27	−0·40
6	XXI	62·36	+1·69	8	XXIII	59·75	−0·92
	Mean	19 56 61·08		8	XIII	59·02	−1·65
				8	XIV	61·07	+0·40
				8	I	61·70	+1·03
				9	X	60·66	−0·01
				9	XI	61·53	+0·86
				9	XII	60·05	−0·62
					Mean	19 56 60·26	

	° ′ ″	″
Mean of two groups	19 56 60·67	±0·14
Diurnal aberration	−0·32	
Azimuth of Mark	160 02 59·65	±0·14
Angle between Mark and Mount Nebo	196 16 30·84	
Azimuth of Mount Nebo	356 19 30·49	

(51) ANTELOPE, UTAH.

$\varphi = 40° 57'·7$. $\lambda = 112° 13'·0$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was about 8 kilometres distant. Observer, P. A. Welker; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ± 0″·65.

Summary of results for azimuth at Antelope, Utah.

Hour angle of star 7^h to 9^h.				Hour angle of star 16^h to 18^h.			
Date, 1892.	Position.	Mark W. of N.	Δ	Date, 1892.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Oct. 23	I	11 21 45·67	−1·68	Oct. 24	IV	11 21 48·38	+1·03
23	II	47·30	−0·05	24	V	47·82	+0·47
23	III	46·49	−0·86	24	VI	47·66	+0·31
24	VII	47·17	−0·18	25	X	48·47	+1·12
24	VIII	46·51	−0·84	25	XI	47·05	−0·30
24	IX	46·16	−1·19	25	XII	47·84	+0·49
25	XIII	45·24	−2·11	26	XVI	47·57	+0·22
25	XIV	47·08	−0·27	26	XVII	48·49	+1·14
25	XV	47·97	+0·62	26	XVIII	47·90	+0·55
26	XIX	48·49	+1·14	27	XXII	[45·18]	Rejected.
26	XX	47·52	+0·17				
26	XXI	45·84	−1·51				
	Mean	11 21 46·79			Mean	11 21 47·91	

	° ′ ″ ″
Mean of groups	11 21 47·35 ±0·14
Diurnal aberration	−0·32
Azimuth of Mark	168 38 12·97 ±0·14
Angle between Deseret and Mark	136 39 09·09
Azimuth of Deseret	31 59 03·88

(52) PROMONTORY, UTAH.

$\varphi = 41° 17'.8$. $\lambda = 112° 25'.2$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The mark was about 3 kilometres distant. Observer, W. Eimbeck; computer, D. L. Hazard.. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ±0″·77.

Summary of results for azimuth at Promontory, Utah.

Near Upper Culmination.				Near Lower Culmination.			
Date, 1892.	Position.	Mark W. of N.	Δ	Date, 1892.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
July 11	IX	39 09 14·40	−1·21	July 12	XIII	39 09 15·28	−0·33
11	X	16·25	+0·64	12	XIV	16·42	+0·81
11	XI	14·35	−1·26	12	XV	13·79	−1·82
11	XII	14·00	−1·61	13	XX	13·61	−2·00
12	XVI	16·32	+0·71	13	XXI	15·75	+0·14
12	XVII	17·32	+1·71	13	XXII	15·75	+0·14
12	XIX	16·50	+0·89	14	IV	16·00	+0·39
12	XXIII	15·95	+0·34	14	V	14·55	−1·06
13	XXIII	15·30	−0·31	14	VI	17·55	+1·94
13	I	14·43	−1·18	14	VII	15·96	+0·35
13	II	17·57	+1·96	15	VIII	16·44	+0·83
13	III	15·75	+0·14	15	XXIII	15·49	−0·12
	Mean	39 09 15·68			Mean	39 09 15·55	

	° ′ ″ ″
Mean of groups	39 09 15·61 ±0·16
Diurnal aberration	−0·32
Azimuth of Mark	140 50 44·71 ±0·16
Angle between Mark and Ogden Peak	142 33 17·83
Azimuth of Ogden Peak	283 24 02·54

(53) DESERET, UTAH.

$\varphi = 40° \ 27'\cdot5.$ $\lambda = 112° \ 37'\cdot6$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was 15·92 kilometres distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ± 0″·86.

Summary of results for azimuth at Deseret, Utah.

Hour angle of star 4^h to 6^h.				Hour angle of star 14^h to 16^h.			
Date, 1892.	Position.	Mark E. of N.	Δ	Date, 1892.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Sept. 7	VIII	3 23 09·97	+0·69	Sept. 7	VIII	3 23 08·90	−0·38
7	IX	10·47	+1·19	8	X	07·59	−1·69
8	XIII	09·69	+0·41	8	XI	07·57	−1·71
8	XIV	10·17	+0·89	8	XII	08·83	−0·45
8	XV	09·40	+0·12	9	XVI	07·18	−2·10
9	XIX	11·03	+1·75	9	XVII	08·06	−1·22
9	XX	09·01	−0·27	9	XVIII	09·71	+0·43
9	XXI	11·24	+1·96	10	XXII	08·40	−0·58
10	II	10·58	+1·30	10	XXIII	09·77	+0·49
10	III	10·17	+0·89	10	I	08·82	−0·46
10	IV	11·28	+2·00	11	V	06·69	−2·59
11	V	10·51	+1·23	11	VI	08·24	−1·04
11	XVI	09·88	+0·60	11	VII	08·11	−1·17
	Mean	3 23 10·26			Mean	3 23 08·30	

	° ′ ″	″
Mean of groups	3 23 09·28	± 0·17
Diurnal aberration	+ 0·32	
Azimuth of Mark	183 23 09·60	± 0·17
Angle between Mark and Mount Nebo	130 50 51·51	
Azimuth of Mount Nebo	314 14 01·11	

(54) IBEPAH, UTAH.

$\varphi = 39° \ 49'\cdot7.$ $\lambda = 113° \ 55'\cdot2$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was at North Ibepah Peak, 1·9 miles distant. Observers, W. Eimbeck and P. A. Welker; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, and 2 pointings on the mark. Probable error of a single set = ± 0″·70.

Summary of results for azimuth at Ibepah, Utah.

Hour angle of star 4^h to 6^h.				Hour angle of star 14^h to 16^h.			
Date, 1889.	Position.	Mark E. of N.	Δ	Date, 1889.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Sept. 6	I	22 11 53·70	+0·43	Sept. 6	I	22 11 54·01	+0·74
6	II	50·82	−2·45	7	IV	53·36	+0·09
6	III	54·21	+0·94	7	V	51·51	−1·76
7	VII	54·67	+1·40	7	VI	53·04	−0·23
7	VIII	53·28	+0·01	8	X	51·79	−1·48
7	IX	55·12	+1·85	8	XI	53·37	+0·10
8	XIII	52·62	−0·65	8	XII	53·72	+0·45
8	XIV	53·97	+0·70	9	XVI	52·39	−0·88
8	XV	53·51	+0·24	9	XVII	53·48	+0·21
9	XIX	53·52	+0·25	9	XII	54·26	+0·99
9	XX	53·39	+0·12	10	XVIII	52·21	−1·06
				10	VI	[57·72]	Rejected
	Mean	22 11 53·53			Mean	22 11 53·01	

	° ′ ″ ″
Mean of groups	22 11 53·27 ±0·15
Diurnal aberration	+0·32
Azimuth of Mark	202 11 53·59 ±0·15
Angle between Diamond Peak and Mark	121 00 25·13
Azimuth of Diamond Peak	81 11 28·46

10. NEVADA SERIES.

(55) PIOCHE, NEVADA.

$\varphi = 37° 59'·1$. $\lambda = 114° 03'·2$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was about a mile and a half distant. Observer, W. Eimbeck; computers, A. S. Christie and E. Smith. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointing on the mark. Probable error of a single result = ± 0″·66.

Summary of results for azimuth at Pioche, Nevada.

Near Eastern Elongation.				Near Western Elongation.			
Date, 1883.	Position.	Mark W. of N.	Δ	Date, 1883.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Sept. 18	I	164 31 15·82	+0·46	Sept. 18	III	164 31 15·71	+0·35
18	II	15·43	+0·07	18	V	14·25	−1·11
19	VII	14·78	−0·58	18	VI	15·93	+0·57
19	VIII	16·12	+0·76	19	X	17·45	+2·09
19	IX	15·77	+0·41	20	XII	15·85	+0·49
20	XI	16·77	+1·41	20	XIII	13·47	−1·89
21	XVI	14·19	−1·17	20	XIV	14·99	−0·37
21	XVII	13·96	−1·40	20	XV	16·62	+1·26
21	XVIII	15·84	+0·48	20	XIX	14·97	−0·39
22	XIX	16·25	+0·89	20	XXII	14·76	−0·60
22	XXIV	14·56	−0·80	20	XXIII	16·63	+1·27
22	XXV	13·85	−1·51	21	XX	15·14	−0·22
24	IV	15·31	−0·05	21	XXI	15·04	−0·32
	Mean	164 31 15·28			Mean	164 31 15·44	

	° ′ ″ ″
Mean of two groups	164 31 15·36 ±0·13
Diurnal aberration	−0·32
Azimuth of Mark	15 28 44·96 ±0·13
Angle between Mark and Tushar	235 30 05·19
Azimuth of Tushar	250 58 50·15

(56) PILOT PEAK, NEVADA.

$\varphi = 41° 01'·1$. $\lambda = 114° 04'·7$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was 1¾ miles distant. Observer, W. Eimbeck; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on star, 2 pointings on the mark. Probable error of a single result = ±0″·81.

Summary of results for azimuth at Pilot Peak, Nevada.

Near Upper Culmination.				Near Lower Culmination.			
Date, 1889.	Position.	Mark E. of N.	Δ	Date, 1889.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
July 18	III	12 33 36·33	+0·13	July 18	I	12 33 36·34	+0·14
18	IV	35·87	−0·33	18	II	34·54	−1·66
18	V	37·42	+1·22	19	VII	33·40	−2·80
18	VI	36·90	+0·70	19	VIII	35·69	−0·51
19	VIII	36·51	+0·31	20	XII	35·53	−0·67
19	IX	37·99	+1·79	20	XIII	34·90	−1·30
19	X	36·88	+0·68	20	XIV	35·92	−0·28
19	XI	36·35	+0·15	20	XV	36·91	+0·71
20	XVII	37·39	+1·19	20	XVI	35·53	−0·67
20	I	38·64	+2·44		Mean	12 33 35·42	
20	VI	36·35	+0·15				
	Mean	12 33 36·97					

	° ′ ″ ″
Mean of two groups	12 33 36·20 ±0·18
Diurnal aberration	+0·32
Azimuth of Mark	192 33 36·52 ±0·18
Angle between Mark and Mount Nebo	111 06 37·49
Azimuth of Mount Nebo	303 40 14·01

(57) DIAMOND PEAK, NEVADA.

$\varphi = 39° 35'·1$. $\lambda = 115° 49'·1$ West of Greenwich.

Results for azimuth from observations of Polaris near Eastern and Western Elongations.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was about 5 miles distant. Observer, W. Eimbeck; computers, A. S. Christie and E. Smith. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result near Eastern Elongation = ± 0''·54, and near Western Elongation = ± 0''·41.

Summary of results for azimuth at Diamond Peak, Nevada.

Near Eastern Elongation.				Near Western Elongation.			
Date, 1881.	Position.	Mark W. of N.	Δ	Date, 1881.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Sept. 17	IX	2 45 32·14	+0·02	Sept. 21	XXII	2 45 30·51	−0·47
18	X	31·47	−0·65	24	XXV	29·85	−1·13
18	XI	33·57	+1·45	24	I	31·33	+0·35
19	XII	32·85	+0·73	24	II	30·96	−0·02
19	XIII	33·17	+1·05	26	VIII	30·61	−0·37
20	XIV	32·14	+0·02	26	XVI	32·03	+1·05
20	XV	32·45	+0·33	29	XIX	31·20	+0·22
24	XXIII	31·77	−0·35	29	XX	30·64	−0·34
24	XXIV	31·86	−0·26	29	XXI	31·08	+0·10
25	III	32·31	+0·19	30	XVIII	30·85	−0·13
25	IV	31·93	−0·19	30	XVII	31·77	+0·79
25	V	32·01	−0·11		Mean	2 45 30·98	±0·12
26	VI	30·22	−1·90				
26	VII	31·77	−0·35				
	Mean	2 45 32·12	±0·10				

	° ′ ″ ″
Mean of two groups	2 45 31·55 ± 0·13
Diurnal aberration	− 0·32
Azimuth of Mark	177 14 28·77 ± 0·13
Angle between Mount Callahan and Mark	78 47 14·81
Azimuth of Mount Callahan	98 27 13·96

(58) MOUNT CALLAHAN, NEVADA.

$\varphi = 39° 42'·5$. $\lambda = 116° 57'·1$ West of Greenwich.

Results for azimuth from observations of Polaris near Upper and Lower Culminations.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The mark was a little more than 6 miles distant. Observer, W. Eimbeck; computers, A. S. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 2 pointings on the star, reversal of instrument, 2 pointings on the star, 2 pointings on the mark. Probable error of a single result = ± 0''·79 for Upper Culmination and ± 0''·60 for Lower Culmination.

Summary of results for azimuth at Mount Callahan, Nevada.

Upper Culmination.				Lower Culmination.			
Date, 1881.	Position.	Mark E. of N.	Δ	Date, 1881.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
July 21	XVIII	29 39 60·62	+0·66	July 21	XXI	29 39 58·42	−0·13
21	XIX	58·01	−1·95	21	XXII	59·06	+0·51
21	XX	59·70	−0·26	21	XXIII	58·04	−0·51
22	XXIV	59·87	−0·09	22	II	59·28	+0·73
22	XXV	61·52	+1·56	22	III	58·95	+0·40
22	I	61·98	+2·02	22	IV	58·70	+0·15
23	V	60·84	+0·88	23	VIII	58·92	+0·37
23	VI	60·37	+0·41	23	IX	59·29	+0·74
23	VII	59·84	−0·12	28	XIX	56·79	−1·76
25	X	59·88	−0·08	28	XX	57·13	−1·42
25	XI	59·58	−0·38	28	XXI	59·46	+0·91
25	XII	59·76	−0·20		Mean	29 39 58·55	±0·18
27	XIII	61·57	+1·61				
27	XIV	59·83	−0·13				
27	XV	57·97	−1·99				
28	XVI	57·87	−2·09				
28	XVII	60·45	+0·49				
28	XVIII	59·65	−0·31				
	Mean	29 39 59·96	±0·19				

	° ′ ″	″
Mean of two groups	29 39 59·26	±0·16
Diurnal aberration	+0·32	
Azimuth of Mark	202 39 59·58	
Angle between Carson Sink and Mark	126 30 24·64	
Azimuth of Carson Sink	83 09 34·94	

(59) TOIYABE DOME, NEVADA.

$\varphi = 38° 49'.9$. $\lambda = 117° 21'.2$ West of Greenwich.

Results for azimuth from observations of Polaris near Eastern and Western Elongations and δ Ursæ Minoris near Lower Culmination.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark, called Ophir, was about 7 miles distant. Observer, W. Eimbeck; computers, A. S. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 3 pointings on the star, then reversal of instrument followed by similar pointings on star and mark. Probable error of a single result = ± 0″·62.

Summary of results for azimuth at Toiyabe Dome, Nevada.

Date, 1880.	Position.	Star.	Phase.	Mark E. of N.	Δ	Date, 1880.	Position.	Star.	Phase.	Mark E. of N.	Δ
				° ′ ″	″					° ′ ″	″
Sept. 20	I	α U. M.	W. E.	13 21 52·07	+0·93	Sept. 24	X	α U. M.	E. E.	13 21 51·51	+0·37
21	XVIII	δ U. M.	L. C.	51·37	+0·23	25	XXIII	α U. M.	E. E.	50·89	−0·25
21	II	α U. M.	W. E.	52·18	+1·04	26	XI	δ U. M.	L. C.	51·10	−0·04
22	III	α U. M.	W. E.	50·82	−0·32	26	XII	α U. M.	W. E.	50·59	−0·55
23	IV	δ U. M.	L. C.	51·99	+0·85	28	XIII	α U. M.	E. E.	50·79	−0·35
23	V	α U. M.	W. E.	50·45	−0·69	28	XIII	α U. M.	E. E.	51·65	+0·51
23	VI	α U. M.	W. E.	51·73	+0·59	29	XIV	α U. M.	W. E.	51·26	+0·12
24	VII	δ U. M.	L. C.	50·14	−1·00	29	XV	α U. M.	W. E.	50·09	−1·05
24	VII	δ U. M.	L. C.	50·21	−0·93	30	XVI	α U. M.	W. E.	51·70	+0·56
24	VIII	α U. M.	W. E.	52·37	+1·23	30	XVII	α U. M.	W. E.	52·37	+1·23
24	IX	α U. M.	E. E.	48·71	−2·43						

	° ′ ″	″
Mean	13 21 51·14	±0·13
Diurnal aberration	+0·32	
Azimuth of Mark	193 21 51·46	±0·13
Angle between Mount Grant and Mark	116 01 02·16	
Azimuth of Mount Grant	77 20 49·30	

(60) CARSON SINK, NEVADA.

$\varphi = 39° 35'.0$. $\lambda = 118° 14'.2$ West of Greenwich.

Results for azimuth from observations of Polaris near Upper and Lower Culminations.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The mark was about 6.4 miles distant. Observer, W. Eimbeck; computers, A. S. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark followed by 2 pointings on the star, then reversal of instrument, and similar pointings on star and mark. Probable error of a single result near Upper Culmination = ± 0″.99, near Lower Culmination = ±0″.37.

Summary of results for azimuth at Carson Sink, Nevada.

Polaris near Upper Culmination.				Polaris near Lower Culmination.			
Date, 1880.	Position.	Mark W. of N.	Δ	Date, 1880.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
July 19	XVIII	0 54 32.97	+0.67	July 14	XIV	0 54 32.85	0.00
19	XIX	33.02	+0.72	14	XV	33.25	+0.40
20	XXI	30.72	−1.58	18	XVI	34.01	+1.16
20	XXII	30.98	−1.32	18	XVII	32.67	−0.18
21	XXV	34.26	+1.96	20	XX	32.86	+0.01
21	I	33.05	+0.75	20	XXI	33.65	+0.80
21	II	32.47	+0.17	21	XXIII	32.31	−0.54
22	IV	29.96	−2.34	21	XXIV	32.15	−0.70
22	V	33.50	+1.20	21	XXV	32.39	−0.46
22	VI	33.74	+1.44	22	III	31.89	−0.96
23	IX	33.25	+0.95	22	III	33.43	+0.58
24	XIII	33.65	+1.35	23	VI	33.34	+0.49
26	XIII	32.26	−0.04	23	VII	32.65	−0.20
26	XXIII	30.84	−1.46	23	VIII	32.90	+0.05
26	VII	29.76	−2.54	24	X	32.55	−0.30
	Mean	0 54 32.30	±0.25	24	XI	32.93	+0.08
				24	XII	32.69	−0.16
					Mean	0 54 32.85	±0.09

	° ′ ″ ″
Mean of two groups	0 54 32.58 ± 0.13
Diurnal aberration	− 0.32
Azimuth of Mark	179 05 27.74 ± 0.13
Angle between Mark and Mount Callahan	83 14 57.91
Azimuth of Mount Callahan	262 20 25.65

(61) MOUNT CONNESS, CALIFORNIA.

$\varphi = 37° 57'.9$. $\lambda = 119° 19'.3$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite was mounted over the triangulation station. The azimuth mark was on Mount Hoffmann, about 13½ miles distant. Observer, G. Davidson; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 4 pointings on the mark, 6 pointings on the star, reversal of instrument, 6 pointings on the star, 4 pointings on the mark. Probable error of a single result $= \pm 1''.01$.

Summary of results for azimuth at Mount Conness, California.

Date, 1890.	Position.	Mark W. of N.	Δ	Date, 1890.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Aug. 13	VI	129 37 01·96	−0·99	Aug. 20	XLV	129 37 05·24	+2·29
14	VII	02·55	−0·40	21	XLVII	02·98	+0·03
14	VIII	02·00	−0·95	21	III	02·82	−0·13
15	XV	02·28	−0·67	21	XXV	01·41	−1·54
16	XXI	04·88	+1·93	22	XII	36 59·16	−3·79
16	XXII	02·53	−0·42	22	XL	37 03·50	+0·55
17	XXVII	00·64	−2·31	23	XIII	00·32	−2·63
17	XXVIII	03·46	+0·51	23	XVII	04·16	+1·21
18	XXIX	02·81	−0·14	23	XIX	03·16	+0·21
18	XXXIII	04·76	+1·81	24	XXXI	05·34	+2·39
18	XXXIV	04·81	+1·86	24	XLII	02·28	−0·67
19	XXXVI	01·95	−1·00	25	X	02·35	−0·60
19	XXXIX	04·11	+1·16	25	IV	03·60	+0·65
19	I	05·14	+2·19	26	XXIII	02·89	−0·06
20	XLIV	03·67	+0·72	26	XXXVIII	01·73	−1·22

	° ′ ″	″
Mean	129 37 02·95	±0·19
Diurnal aberration	−0·32	
Azimuth of Mark	50 22 57·37	±0·19
Angle between Mark and Round Top	92 16 21·83	
Azimuth of Round Top	142 39 19·20	

(62) LAKE TAHOE, SOUTHEASTERN END, CALIFORNIA.

$\varphi = 38° 57'.3$. $\lambda = 119° 56'.7$ West of Greenwich.

Results for azimuth from observations of B. A. C. 4165 near Western Elongation and Polaris near Eastern Elongation.—The 50-centimetre direction theodolite No. 115 was mounted on a brick and stone pier near the California-Nevada boundary line, on the southeastern shore of Lake Tahoe. The azimuth mark was near the Tallac House, nearly 6 miles distant across the lake. Observer, G. Davidson; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 5 pointings on the mark, 6 pointings on the star, reversal of instrument, 6 pointings on the star, 5 pointings on the mark. Probable error of a single result from B. A. C. 4165 $= \pm 0''.29$, and for Polaris (rejecting the first set) $= \pm 0''.39$. The apparent declinations of B. A. C. 4165 given in the Connaissance des Temps were diminished by

0''·2, in accordance with a redetermination of the mean declination from all available catalogues.

Summary of results for azimuth at Lake Tahoe, California.

B. A. C. 4165.				Polaris.			
Date, 1893.	Position.	Mark W. of S.	Δ	Date, 1893.	Position.	Mark W. of S.	Δ
		° ' ''	''			° ' ''	''
Aug 22	I	71 33 59·22	−0·14	Aug. 22	I	71 33 [62·81]	Rejected
23	II	59·28	−0·08	23	III	59·53	+0·17
24	IV	59·92	+0·56	24	V	58·83	−0·53
27	VI	59·82	+0·46	27	VII	59·08	−0·28
28	VIII	59·98	+0·62	28	IX	59·38	+0·02
29	X	59·87	+0·51	29	XI	57·82	−1·54
30	XII	60·37	+1·01	30	XIII	59·19	−0·17
31	XIV	59·63	+0·27	31	XV	59·59	+0·23
Sept. 1	XVI	59·05	−0·31	Sept. 1	XVII	58·89	−0·47
	Mean	71 33 59·68			Mean	71 33 59·04	

	° ' '' ''
Mean of two stars	71 33 59·36 ± 0·10
Diurnal aberration	+ 0·32
Azimuth of Mark	71 33 59·68 ± 0·10
Angle between Mark and Folsom Peak	106 22 19·4
Azimuth of Folsom Peak	177 56 19·1

(63) ROUND TOP, CALIFORNIA.

$\varphi = 38° \ 39'·8$. $\lambda = 120° \ 00'·1$ West of Greenwich.

Results for azimuth from observations of B. A. C. 4165 near Western Elongation and Polaris near Eastern Elongation.—The 50-centimetre direction theodolite No. 115 was mounted over the triangulation station. The mark was 5·9 miles distant. Observer, G. Davidson; computers, James Main and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 5 or 6 pointings on the mark, followed by 6 pointings on the star, then reversal of instrument and similar pointings on star and mark. Probable error of a single result—for B. A. C. 4165 = ± 0''·35 and for Polaris = ± 0''·55. The apparent places of Polaris were taken from the American Ephemeris and of B. A. C. 4165 from the Connaissance des Temps. A redetermination of the declination of the latter star from all available catalogues gave a value 0''·32 smaller than the one given in the Connaissance des Temps. The resulting azimuth has been corrected accordingly.

Summary of results for azimuth at Round Top, California.

B. A. C. 4165.				Polaris.			
Date, 1879.	Position.	Mark W. of N.	Δ	Date, 1879.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Aug. 23	V	27 33 23·10	+0·05	Aug. 20	IV	27 33 23·34	+0·59
24	II	23·14	+0·09	23	VI	22·45	−0·30
25	VII	23·57	+0·52	24	III	22·71	−0·04
26	IX	22·89	−0·16	25	VIII	21·64	−1·11
28	XI	23·63	+0·58	26	X	22·89	+0·14
30	XVI	21·79	−1·26	28	XII	24·23	+1·48
31	XVIII	22·80	−0·25	29	XIV	21·18	−1·57
Sept. 1	I	23·04	−0·01	30	XV	22·64	−0·11
2	XXII	23·16	+0·11	31	XVII	22·06	−0·69
3	XIX	23·85	+0·80	Sept. 1	XXIII	22·54	−0·21
4	II	22·71	−0·34	2	XXI	23·85	+1·10
5	X	22·87	−0·18	3	XX	23·23	+0·48
				4	IV	22·59	−0·16
				5	VI	23·20	+0·45
Mean		27 33 23·05	±0·10	Mean		27 33 22·75	±0·15

	″	° ′ ″ ″
Corrected for change in δ,	23·46	
Mean of two stars		27 33 22·90 ±0·09
Diurnal aberration		− 0·32
Azimuth of Mark		152 26 37·42 ±0·09
Angle between Mount Helena and Mark		61 27 43·65
Azimuth of Mount Helena		90 58 53·77

(64) MOUNT LOLA, CALIFORNIA.

$\varphi = 39° 26'·0$. $\lambda = 120° 21'·9$ West of Greenwich.

Results for azimuth from observations of Polaris near Eastern Elongation and B. A. C. 4165 near Western Elongation.—The 50-centimetre direction theodolite No. 115 was mounted over the triangulation station. The azimuth mark was on the summit of Webber Hill, 5·3 miles distant. Observer, G. Davidson; computers, James Main and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 4 to 6 pointings on the mark followed by 6 or 7 pointings on the star, then reversal of instrument and similar pointings on star and mark. Probable error of a single result for B. A. C. 4165 = ± 0″·71 and for Polaris = ± 0″·70. The apparent places for Polaris were taken from the American Ephemeris, those of B. A. C. 4165 from the Connaissance des Temps. A redetermination of the declination of B. A. C. 4165 from all available catalogues gave a value 0″.32 smaller than the one given in Connaissance des Temps. The resulting azimuth has been corrected accordingly.

Summary of results for azimuth at Mount Lola, California.

	B. A. C. 4165.				Polaris.		
Date, 1879.	Position.	Mark W. of N.	Δ	Date, 1879.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
July 9	XIX	52 44 59·83	−1·18	July 9	XVIII	52 44 61·00	−0·52
13	XXI	60·50	−0·51	13	XX	59·51	−2·01
14	XXII	60·17	−0·84	14	I	60·31	−1·21
15	XXIII	61·15	+0·14	15	II	62·37	+0·85
16	XI	61·06	+0·05	16	III	61·46	−0·06
17	IV	59·56	−1·45	17	V	62·06	+0·54
18	XV	62·05	+1·04	18	XIV	60·85	−0·67
19	XVII	60·39	−0·62	19	XVI	62·04	+0·52
20	XIII	59·97	−1·04	20	XII	60·77	−0·75
21	X	63·10	+2·09	21	IX	61·19	−0·33
22	VIII	61·17	+0·16	22	VII	62·69	+1·17
23	VI	62·26	+1·25	23	XIX	63·14	+1·62
24	XXI	61·88	+0·87	24	XXII	62·34	+0·82
	Mean	52 44 61·01	±0·20		Mean	52 44 61·52	±0·19

	° ′ ″ ″	° ′ ″ ″
Correction for change in δ	+0·41	
	52 44 61·42 ±0·20	
Mean of two stars		52 45 01·47 ±0·14
Diurnal aberration		−0·32
Azimuth of Mark		127 14 58·85 ±0·14
Angle between Mount Helena and Mark		59 52 56·45
Azimuth of Mount Helena		67 22 02·40

(65) MOCHO, CALIFORNIA.

$\varphi = 37° 28'.6$. $\lambda = 121° 33'.4$ West of Greenwich.

Results for azimuth from observations of Polaris near Eastern Elongation and δ Ursæ Minoris near Western Elongation.—The 50-centimetre direction theodolite No. 115 was mounted over the triangulation station. The azimuth mark was at Livermore Mountain, about 9 miles distant. Observer, J. S. Lawson; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 5 pointings on the mark, 6 pointings on the star, followed by reversal of instrument and then the same number of pointings on star and mark in the reverse order. Probable error of a single result = ± 1″·04.

Summary of results for azimuth at Mocho, California.

Date, 1887.	Position.	Star.	Mark W. of N.	Δ	Date, 1887.	Position.	Star.	Mark W. of N.	Δ
			° ′ ″	″				° ′ ″	″
Sept. 7	VI	Polaris	20 40 47·08	+0·59	Sept. 20	XXI	Polaris	20 40 46·52	−1·15
8	VII		47·63	−0·04	23	XXII		44·96	−2·81
9	VIII		49·26	+1·59	24	XXIII		45·90	−1·77
10	X		50·26	+2·59	25	I		47·96	+0·29
11	XI		44·95	−2·72	26	II		48·84	+1·17
12	XII		50·89	+3·22	27	III		47·36	−0·31
13	IX		48·54	+0·87	28	IV		48·09	+0·42
14	XIV		47·37	−0·30	28	V	δ Urs. Min.	47·45	−0·22
15	XIII		48·09	+0·42	29	XVII	Polaris	46·46	−1·21
16	XVI		49·08	+1·41	30	XVIII		47·08	−0·59
18	XIX		46·94	−0·73	30	XV		45·75	−1·92
19	XX		49·65	+1·98	Oct. 1	VI		48·07	+0·40

	° ′ ″ ″
Mean	20 40 47·67 ±0·21
Diurnal aberration	−0·32
Azimuth of Mark	159 19 12·65 ±0·21
Angle between Mount Diablo and Mark	14 21 36·89
Azimuth of Mount Diablo	144 57 35·76

(66) SOUTHEAST YOLO BASE, CALIFORNIA.

$\varphi = 38^\circ\ 31'.6$. $\lambda = 121^\circ\ 48'.0$ West of Greenwich.

Results for azimuth from observations of B. A. C. 4165 near Western Elongation and Polaris near Eastern Elongation.—The 50-centimetre direction theodolite No. 115 was mounted over the triangulation station at the southeast end of the Yolo Base. The mark was at the other end of the base, nearly 11 miles distant. Observer, G. Davidson; computers, A. S. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 5 pointings on the mark followed by 6 pointings on the star, then reversal of instrument and similar pointings on star and mark. Probable error of a single result for B. A. C. 4165 = $\pm 0''.79$ and for Polaris = $\pm 0''.75$. The apparent places of Polaris were taken from the American Ephemeris and of B. A. C. 4165 from the Connaissance des Temps. A redetermination of the declination of the latter star from all available catalogues gave a value $0''.33$ smaller than the one given in the Connaissance des Temps. The resulting azimuth has been corrected accordingly.

Summary of results for azimuth at Southeast Yolo Base, California.

B. A. C. 4165.				Polaris.			
Date, 1880.	Position.	Mark W. of N.	Δ	Date, 1880.	Position.	Mark W. of N.	Δ
		° ′ ″				° ′ ″	″
July 25	VI	16 52 49.22	+1.70	July 25	VII	16 52 47.61	+1.40
26	VIII	48.82	+1.30	26	IX	46.71	+0.50
27	X	47.81	+0.29	27	XI	44.90	−1.31
28	XII	46.06	−1.46	28	XIII	46.70	+0.49
29	XIV	48.02	+0.50	29	XV	46.60	+0.39
30	XVI	45.63	−1.89	30	XVII	46.30	+0.09
31	XIX	46.92	−0.60	31	XVIII	47.19	+0.98
Aug. 1	XXI	48.05	+0.53	Aug. 1	XX	45.34	−0.87
2	XXII	48.69	+1.17	2	XXIII	44.01	−2.20
3	I	47.78	+0.26	3	II	47.58	+1.37
4	III	45.96	−1.56	4	IV	45.38	−0.83
5	V	47.31	−0.21	5	VI	46.23	+0.02
	Mean	16 52 47.52	±0.23		Mean	16 52 46.21	±0.22

Corrected for change in δ $16^\circ\ 52'\ 47''.93$

	° ′ ″	″
Mean of two stars	16 52 47.07	±0.16
Diurnal aberration	−0.32	
Azimuth of N. W. Yolo Base	163 07 13.25	±0.16

(67) NORTHWEST YOLO BASE, CALIFORNIA.

$\varphi = 38^\circ\ 40'.6$. $\lambda = 121^\circ\ 51'.5$ West of Greenwich.

Results for azimuth from observations of B. A. C. 4165 near Western Elongation and Polaris near Eastern Elongation. The 50-centimetre direction theodolite No. 115 was mounted over the triangulation station at the northwest end of the Yolo Base. The azimuth mark was at the other end of the base, nearly 11 miles distant. Observer, G. Davidson; computers, A. S. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 5 pointings on the mark followed by 6 pointings on the star, then reversal of instrument and similar pointings on star and

mark. Probable error of a single result from B. A. C. 4165 = ± 0''·66 and from Polaris = ± 0''·63. The apparent places of Polaris are taken from the American Ephemeris; those of B. A. C. 4165 from the Connaissance des Temps. A redetermination of the declination of the latter star from all available catalogues gave a value of 0''·33 smaller than the one given in the Connaissance des Temps. The resulting azimuth has been corrected accordingly.

Summary of results for azimuth at Northwest Yolo Base, California.

B. A. C. 4165.				Polaris.			
Date, 1880.	Position.	Mark E. of N.	Δ	Date, 1880.	Position.	Mark, E. of N.	Δ
		° ' ''	''			° ' ''	''
Aug. 19	I	163 05 00·72	−0·96	Aug. 19	II	163 05 00·71	−1·70
20	IV	00·02	−1·66	20	V	03·16	+0·75
21	VI	01·02	−0·66	21	VII	03·60	+1·19
22	VIII	02·91	+1·23	22	IX	03·52	+1·11
23	X	02·12	+0·44	23	XI	02·95	+0·54
24	XII	02·28	+0·60	24	XIII	02·50	+0·09
25	XIV	01·99	+0·31	25	XV	02·07	−0·34
26	XVII	01·09	−0·59	26	XVI	02·39	−0·02
27	XIX	02·96	+1·28	27	XVIII	01·69	−0·72
28	XX	02·88	+1·20	28	XXI	03·33	+0·92
29	XXII	00·84	−0·84	29	XXIII	01·56	−0·85
30	III	01·29	−0·39	30	VII	01·42	−0·99
	Mean	163 05 01·68	±0·19		Mean	163 05 02·41	±0·18

Corrected for change in δ 163° 05' 01''·27

	° '	''	''
Mean of two stars	163 05	01·84	±0·13
Diurnal aberration		+0·32	
Azimuth of S. E. Yolo Base	343 05	02·16	±0·13

II. WESTERN OR COAST RANGE SERIES.

(68) MOUNT DIABLO, CALIFORNIA.

$\varphi = 37° 52'·8$. $\lambda = 121° 54'·9$ West of Greenwich.

Results for azimuth from observations of Polaris near Eastern Elongation and B. A. C. 4165 near Western Elongation.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was 6¾ miles distant. Observer, G. Davidson; computers, James Main and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 4 pointings on the mark, 4 pointings on the star, then reversal of instrument and 4 more pointings on the star, concluding with 4 pointings on the mark. Probable error of a single result for B. A. C. 4165 = ± 0''·59 and for Polaris = ± 0''·38. The apparent places for Polaris were taken from the American Ephemeris as usual. For B. A. C. 4165 recourse was had to the Connaissance des Temps. Subsequently the mean declination of the latter star was determined from all available catalogues and a result obtained which was 0''·29 smaller than that given in the Connaissance des Temps. A correction corresponding to this difference was applied to the azimuth deduced from the observations on B. A. C. 4165.

Summary of results for azimuth at Mount Diablo, California.

B. A. C. 4165 near Western Elongation.				Polaris near Eastern Elongation.			
Date, 1876.	Position.	Mark W. of N.	Δ	Date, 1876.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
July 28	XI	9 42 25·20	−1·12	July 27	IX	9 42 27·41	+1·27
Aug. 1	I	27·40	+1·08	28	XI	25·91	−0·23
3	IV	26·51	+0·19	Aug. 1	I	26·20	+0·06
4	XXI	26·87	+0·55	3	V	25·64	−0·50
5	V	24·61	−1·71	4	XXII	26·68	+0·54
7	XIII	26·78	+0·46	5	VI	25·72	−0·42
8	XIX	26·52	+0·20	7	VII	25·64	−0·50
9	II	27·21	+0·89	8	XX	26·70	+0·56
10	XIV	25·75	−0·57	9	III	25·84	−0·30
11	X	26·60	+0·28	10	XII	25·43	−0·71
12	XXIII	27·10	+0·78	11	VIII	26·44	+0·30
15	XVII	26·45	+0·13	12	XVIII	25·90	−0·24
15	XVI	25·18	−1·14	15	XV	26·36	+0·22
	Mean	9 42 26·32	±0·17		Mean	9 42 26·14	±0·10

	° ′ ″	° ′ ″	″
Correction for change in δ	+0·43		
	9 42 26·75		
Mean of two stars		9 42 26·44	±0·10
Diurnal aberration		−0·32	
Azimuth of Mark		170 17 33·88	
Angle between Mount Helena and Mark		25 49 18·02	
Azimuth of Mount Helena		144 28 15·86	

(69) VACA, CALIFORNIA.

$\varphi = 38° 22'·4$. $\lambda = 122° 05'·1$ West of Greenwich.

Results for azimuth from observations of δ Ursæ Minoris near Western Elongation and 51 Cephei near Eastern Elongation.—The 50-centimetre direction theodolite No. 15 was mounted over the triangulation station. The azimuth mark was at Southeast Yolo Base, about 18·6 miles distant. Observer, G. Davidson; computers, A. S. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 5 pointings on the mark, 6 pointings on the star, reversal of instrument, 6 pointings on the star, 5 pointings on the mark. Probable error of a single result = ± 1″·37 for δ Ursæ Minoris and ± 1″·35 for 51 Cephei.

Summary of results for azimuth at Vaca, California.

δ Ursæ Minoris.				51 Cephei.			
Date, 1880.	Position.	Mark E. of N.	Δ	Date, 1890.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Nov. 1	II	55 38 39·26	+2·98	Nov. 1	III	55 38 38·05	+2·08
3	IV	35·75	−0·53	3	V	36·29	+0·32
5	VI	37·11	+0·83	5	VII	35·13	−0·84
7	X	36·05	−0·23	6	IX	34·56	−1·41
8	XII	37·34	+1·06	7	XI	35·15	−0·82
9	XIV	38·43	+2·15	8	XIII	36·39	+0·42
10	XVI	34·58	−1·70	9	XV	35·67	−0·30
11	XVIII	35·32	−0·96	10	XVII	32·34	−3·63
12	XX	35·99	−0·29	11	XIX	37·13	+1·16
13	XXII	38·09	+1·81	12	XXI	35·55	−0·42
14	VIII	35·95	−0·33	13	XXIII	36·74	+0·77
24	XVII	31·55	−4·73	14	I	40·58	+4·61
	Mean	55 38 36·28	±0·39	24	XIX	34·03	−1·94
					Mean	55 38 35·97	±0·38

	° ′ ″	″
Mean of two stars	55 38 36·12	±0·27
Diurnal aberration	+0·32	
Azimuth of Southeast Yolo Base	235 38 36·44	±0·27

(70) MONTICELLO, CALIFORNIA.

$\varphi = 38^\circ\ 39'\cdot 8$. $\lambda = 122^\circ\ 11'\cdot 4$ West of Greenwich.

Results for azimuth from observations of δ Ursæ Minoris near Western Elongation and 51 Cephei near Eastern Elongation.—The 50-centimetre direction theodolite No. 115 was mounted over the triangulation station. The mark was at Mount Helena, about 24 miles distant. Observer, G. Davidson; computers, A. S. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 5 pointings on the mark, 6 pointings on the star, reversal of instrument, 6 pointings on the star, 5 pointings on the mark. Probable error of a single result $= \pm 1''\cdot 21$ for δ Ursæ Minoris and $\pm 0''\cdot 77$ for 51 Cephei.

Summary of results for azimuth at Monticello, California.

δ Ursæ Minoris.				51 Cephei.			
Date, 1880.	Position.	Mark W. of N.	Δ	Date, 1880.	Position.	Mark W. of N.	Δ
		° ′ ″	″			° ′ ″	″
Sept. 27	VII	88 55 35·37	+0·67	Sept. 27	VIII	88 55 35·53	+0·15
28	IX	34·89	+0·19	28	X	35·10	−0·28
29	XI	32·60	−2·10	29	XII	34·91	−0·47
30	XIII	33·21	−1·49	30	XIV	36·06	+0·68
Oct. 1	XV	34·76	+0·06	Oct. 1	XVI	36·33	+0·95
3	XVIII	35·74	+1·04	3	XVII	35·01	−0·37
5	XX	37·46	+2·76	5	XIX	37·54	+2·16
6	XXI	38·06	+3·36	6	XXII	35·93	+0·55
8	XXIII	32·10	−2·60	8	I	34·46	−0·92
9	II	34·17	−0·53	9	III	33·07	−2·31
10	IV	33·73	−0·97	10	V	36·08	+0·70
12	VI	34·31	−0·39	12	VII	34·52	−0·86
	Mean	88 55 34·70	±0·35		Mean	88 55 35·38	±0·22

	° ′ ″	″
Mean of two stars	88 55 35·04	±0·21
Diurnal aberration	−0·32	
Azimuth of Mount Helena	91 04 25·28	

(71) MOUNT TAMALPAIS, CALIFORNIA.

$\varphi = 37° 55'·3$. $\lambda = 122° 35'·8$ West of Greenwich.

Results for azimuth from observations of B. A. C. 4165 near Western Elongation and Polaris near Eastern Elongation.—The 50-centimetre direction theodolite No. 115 was mounted over the triangulation station. The mark was at Mount Diablo, 37·3 miles distant. Observer, G. Davidson; computers, A. S. Christie and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 5 pointings on the mark, 6 pointings on the star, reversal of instrument, 6 pointings on the star, 5 pointings on the mark. Probable error of a single result = ±0″·61 for B. A. C. 4165 and ±0″·56 for Polaris. The apparent places of Polaris were taken from the American Ephemeris and of B. A. C. 4165 from the Connaissance des Temps. A redetermination of the declination of the latter star from all available catalogues gave a value 0″·35 smaller than the one given in the Connaisance des Temps. The resulting azimuth has been corrected accordingly.

Summary of results for azimuth at Mount Tamalpais, California.

B. A. C. 4165.				Polaris.			
Date, 1882.	Position.	Mark E. of N.	Δ	Date, 1882.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Sept. 5	XI	94 15 14·44	--0·32	Sept. 5	XII	94 15 13·98	−1·44
6	XIII	13·71	−1·05	6	XVIII	15·62	+0·20
12	XVII	13·38	−1·38	12	XIV	15·64	+0·22
13	XIX	13·88	−0·88	13	XX	15·37	−0·05
19	XXII	15·35	+0·59	19	XXI	15·21	−0·21
20	XVI	15·44	+0·68	20	XV	16·50	+1·08
21	I	16·23	+1·47	21	XXIII	15·26	−0·16
22	V	14·70	−0·06	22	IV	15·44	+0·02
26	IX	16·10	+1·34	26	X	15·36	−0·06
Oct. 4	VIII	14·90	+0·14	Oct. 4	VII	16·89	+1·47
7	II	14·25	−0·51	7	III	15·74	+0·32
8	VI	14·71	−0·05	8	IV	14·01	−1·41
	Mean	94 15 14·76	±0·18		Mean	94 15 15·42	±0·16

	° ′ ″	″
Corrected for change in δ	14·25	
Mean of two stars	94 15 14·84	±0·15
Diurnal aberration	+0·32	
Azimuth of Mount Diablo	274 15 15·14	

(72) MOUNT HELENA, CALIFORNIA.

$\varphi = 38° 40'·0$. $\lambda = 122° 38'·0$ West of Greenwich.

Results for azimuth from observations of δ Ursæ Minoris near Western Elongation ana 51 Cephei near Eastern Elongation.—The 50-centimetre direction theodolite No. 5 was mounted over the triangulation station. The azimuth mark was about 7⅓ miles distant in the direction of Middleton. The Hassler telescope was also mounted as a collimator for experimental purposes, but it did not give results as satisfactory as the ordinary mark. Observer, G. Davidson; computers, James Main and A. Ziwet. A single result for azimuth is derived from a set of observations consisting of 4 to 6 pointings on the mark, 4 pointings on the star, then reversal of instrument followed by similar pointings

on star and mark. Probable error of a single result from δ Ursæ Minoris $= \pm 0''.51$ and from 51 Cephei $= \pm 0''.68$. The apparent places of the stars were taken from the American Ephemeris, with corrections to the right ascensions and with a correction to the declination of 51 Cephei derived from a redetermination from the best available catalogues.

Summary of results for azimuth at Mount Helena, California.

δ Ursæ Minoris near Western Elongation.				51 Cephei near Eastern Elongation.			
Date, 1876.	Position.	Mark E. of N.	Δ	Date, 1876.	Position.	Mark E. of N.	Δ
		° ′ ″	″			° ′ ″	″
Oct. 12	XIII	9 18 13.85	+0.17	Oct. 13	XIV	9 18 15.24	+0.51
13	XV	13.95	+0.27	14	XI	14.19	−0.54
14	XII	14.52	+0.84	18	XVII	16.59	+1.86
18	XVI	14.15	+0.47	22	XXII	13.17	−1.56
22	XXI	14.10	+0.42	23	I	13.98	−0.75
23	XXIII	13.77	+0.09	29	IX	16.16	+1.43
29	X	12.22	−1.46	31	VII	14.72	−0.01
31	VIII	12.50	−1.18	Nov. 1	V	14.91	+0.18
Nov. 1	VI	13.51	−0.17	2	III	14.77	+0.04
2	IV	12.99	−0.69	5	XX	14.51	−0.22
5	II	13.98	+0.33	6	XIX	13.78	−0.95
6	XVIII	14.63	+0.95				
	Mean	9 18 13.68	±0.15		Mean	9 18 14.73	±0.20

	° ′ ″ ″
Mean of two stars	9 18 14.20 ±0.13
Diurnal aberration	+0.32
Azimuth of Mark	189 18 14.52 ±0.13
Angle between Mark and Mount Diablo	134 43 10.54
Azimuth of Mount Diablo	324 01 25.06

(73) PAXTON, CALIFORNIA.

$\varphi = 39°\ 08'.0$. $\lambda = 123°\ 18'.8$ West of Greenwich.

Results for azimuth from observations of Polaris at various hour angles.—The 50-centimetre direction theodolite No. 115 was mounted over the triangulation station. The mark was about 1½ miles distant. Observer, C. H. Sinclair; computer, D. L. Hazard. A single result for azimuth is derived from a set of observations consisting of 2 pointings on the mark, 3 pointings on the star, reversal of instrument, 3 pointings on the star, 2 pointings on the mark. Probable error of a single result $= \pm 0''.79$.

Summary of results for azimuth at Paxton, California.

Date, 1897.	Position.	Mark W. of N.	Mean of position.	Δ	Date, 1897.	Position.	Mark W. of N.	Mean of position.	Δ
		° ′ ″	″	″			° ′ ″	″	″
Nov. 3	I	37 47 09·8			Oct. 30	IX	37 47 10·1		
3	I	10·5	10·2	0·0	30	IX	10·2	10·2	0·0
Oct. 28	II	11·2			31	X	10·7		
28	II	10·3			31	X	08·5	09·6	−0·6
Nov. 3	II	10·5			31	XI	10·8		
5	II	14·8	11·7	+1·5	31	XI	10·4	10·6	+0·4
Oct. 28	III	12·2			31	XII	08·8		
28	III	10·7			31	XII	09·7	09·2	−1·0
Nov. 5	III	10·6			Nov. 1	XIII	08·7		
5	III	12·6	11·5	+1·3	1	XIII	09·1	08·9	−1·3
Oct. 29	IV	10·2			1	XIV	11·5		
29	IV	10·4	10·3	+0·1	1	XIV	12·6	12·0	+1·8
29	V	11·3			1	XV	11·0		
29	V	12·6	12·0	+1·8	1	XV	09·9	10·4	+0·2
29	VI	09·4			Nov. 3	XVI	09·3		
29	VI	10·9	10·2	0·0	3	XVI	09·2	09·2	−1·0
30	VII	08·5			3	XVII	08·5		
30	VII	08·8	08·6	−1·6	3	XVII	09·3	08·9	−1·3
30	VIII	09·3							
30	VIII	09·3	09·3	−0·9					

	° ′ ″	″
Mean	37 47 10·17	±0·18
Diurnal aberration	−0·32	
Azimuth of Mark	142 12 50·15	±0·18
Angle between Mark and Mount Sanhedrin	61 34 15·65	
Azimuth of Mount Sanhedrin	203 47 05·80	

(C) SYNOPSIS OF RESULTS OF ASTRONOMIC DETERMINATIONS OF AZIMUTH.

No.	Station occupied.	State.	Year.	Station referred to.	Azimuth (west of south).	Probable error.*	Correction for variation of pole.	Resulting seconds.
					° ′ ″	″	″	″
1	Cape Henlopen L. H.	Del.	1897	Brandywine Shoal L. H.	173 45 17·33	±0·21	+0·31	17·64
2	Principio	Md.	1866	Turkey Point	1 34 43·51	0·40	−0·01	43·50
3	Calvert	Md.	1871	Meekin Neck	252 06 08·93	0·17	+0·25	09·18
4	Marriott	Md.	1849	Hill	96 37 43·36	0·48	+0·04	43·40
5	Webb	Md.	1850	Soper	88 59 49·24	0·21	+0·14	49·38
6	Hill	Md.	1850	Webb	219 46 57·89	0·26	+0·22	58·11
7	Soper	Md.	1850	Webb	268 49 23·46	0·29	+0·14	23·60
8	Seaton	D. C.	1868–69	Hill	265 32 53·76	0·18	−0·15	53·61
9	Causten	D. C.	1851	Soper	210 54 41·78	0·37	−0·13	41·65
10	Sugar Loaf	Md	1879	Bull Run	32 29 16·79	0·20	+0·18	16·97
11	Maryland Heights	Md.	1870	Bull Run	358 43 06·88	0·18	+0·30	07·18
12	Bull Run	Va.	1871	Peach Grove	263 53 28·15	0·20	+0·34	28·49
13	Clark Mount	Va.	1871	Bull Run	202 19 27·77	0·18	+0·21	27·98
14	Long Mount	Va.	1875	Spear	223 28 41·74	0·23	−0·10	41·64
15	Elliott Knob	Va.	1878	Humpback	303 25 24·37	0·27	+0·09	24·46
16	Keeney	W. Va.	1880	Bald Knob	257 04 35·94	0·21	−0·05	35·89
17	Piney	W. Va.	1883	Gebhardt	119 04 31·53	0·26	+0·31	31·84
18	Gould	Ohio	1885	Howland	84 49 13·36	0·26	+0·25	13·61
19	Minerva	Ky.	1887	Ash Ridge	210 54 42·47	0·28	−0·09	42·38
20	Reizin	Ind.	1889	Tanner	276 56 45·93	0·22	+0·09	46·02
21	Weed Patch	Ind.	1889	Fountain	7 33 21·14	0·51	+0·14	21·28

* This does not include the probable error of the angle connecting the azimuth mark with the triangulation station.

(C) SYNOPSIS OF RESULTS, ETC.—Continued.

No.	Station occupied.	State.	Year.	Station referred to.	Azimuth (west of south).	Probable error.	Correction for variation of pole.	Resulting seconds.
					° ′ ″	″	″	″
22	Osborn	Ind.	1887	Calvary	192 16 17·71	0·24	−0·12	17·59
23	Parkersburg	Ill.	1879	Denver	143 16 15·44	0·17	+0·11	15·55
24	Newton	Ill.	1883	Claremont	321 29 05·18	0·27	+0·12	05·30
25	Bording	Ill.	1882	Geoffrey	53 25 07·60	0·30	−0·07	07·53
26	Kleinschmidt	Mo.	1871	Insane Asylum	200 09 31·62	0·79	+0·19	31·81
27	Berger	Mo.	1878	Winter	39 12 05·33	0·31	+0·31	05·64
28	Jefferson City	Mo.	1879	Cedar	199 55 37·22	0·47	+0·25	37·47
29	Hunter	Mo.	1880	Christian	221 48 20·62	0·36	−0·13	20·49
30	Adams	Kans.	1888	Clark	11 46 11·93	0·14	+0·01	11·94
31	Salina West Base	Kans.	1896	Salina East Base	248 36 18·08	0·22	+0·24	18·32
32	Russell Southeast	Kans.	1893	Russell Northwest	140 42 59·69	0·15	+0·10	59·79
33	Overland	Colo.	1881	Eureka	284 10 32·73	0·40	−0·11	32·62
34	El Paso East Base	Colo.	1879	El Paso West Base	102 48 04·41	0·59	+0·21	04·62
35	Pikes Peak	Colo.	1895	Mount Ouray	66 05 16·75	0·22	-0·05	16·70
36	Mount Ouray	Colo.	1894	Uncompahgre	70 35 51·35	0·29	0·08	51·27
37	Gunnison	Colo.	1893	Uncompahgre	41 55 00·32	0·20	+0·07	00·39
38	Treasury Mountain	Colo.	1893	Mount Waas	74 45 04·64	0·12	+0·07	04·71
39	Uncompahgre	Colo.	1895	Treasury Mountain	196 42 55·84	0·18	0·00	55·84
40	Grand Junction	Colo.	1895	Chiquita	23 57 24·03	0·49	−0·05	23·98
41	Tavaputs	Colo.	1891	Patmos Head	88 17 40·58	0·16	+0·27	40·85
42	Mount Waas	Utah	1893	Mount Ellen	72 00 16·67	0·20	−0·05	16·62
43	Patmos Head	Utah	1890	Wasatch	66 41 18·68	0·14	+0·02	18·70
44	Mount Ellen	Utah	1891	Patmos Head	195 35 57·61	0·12	+0·28	57·89
45	Wasatch	Utah	1890	Mount Nebo	160 54 02·48	0·11	+0·25	02·73
46	Mount Nebo	Utah	1887	Tushar	20 05 23·21	0·09	−0·15	23·06
47	Salt Lake City	Utah	1893	City Creek	192 02 50·69	0·13	−0·19	50·50
48	Waddoup	Utah	1892	Ogden Peak	180 42 32·68	0·33	−0·13	32·55
49	Ogden Observatory	Utah	1891	Ogden Peak	283 08 44·63	0·09	+0·07	44·70
50	Ogden Peak	Utah	1888	Mount Nebo	356 19 30·49	0·14	−0·12	30·37
51	Antelope	Utah	1892	Deseret	31 59 03·88	0·14	+0·26	04·14
52	Promontory	Utah	1892	Ogden Peak	283 24 02·54	0·16	+0·10	02·64
53	Deseret	Utah	1892	Mount Nebo	314 14 01·11	0·17	+0·27	01·38
54	Ibepah	Utah	1889	Diamond Peak	81 11 28·46	0·15	+0·03	28·49
55	Pioche	Nev.	1883	Tushar	250 58 50·15	0·13	+0·14	50·29
56	Pilot Peak	Nev.	1889	Mount Nebo	303 40 14·01	0·18	+0·14	14·15
57	Diamond Peak	Nev.	1881	Mount Callahan	98 27 13·96	0·13	−0·14	13·82
58	Mount Callahan	Nev.	1881	Carson Sink	83 09 34·94	0·16	−0·10	34·84
59	Toiyabe Dome	Nev.	1880	Mount Grant	77 20 49·30	0·13	−0·01	49·29
60	Carson Sink	Nev.	1880	Mount Callahan	262 20 25·65	0·13	−0·15	25·50
61	Mount Conness	Cal.	1890	Round Top	142 39 19·20	0·19	+0·26	19·46
62	Lake Tahoe Southeast	Cal.	1893	Folsom Peak	177 56 19·[illegible]	0·10	+0·03	19·13
63	Round Top	Cal.	1879	Mount Helena	90 58 53·77	0·09	+0·12	53·89
64	Mount Lola	Cal.	1879	Mount Helena	67 22 02·40	0·14	−0·04	02·36
65	Mocho	Cal.	1887	Mount Diablo	144 57 35·76	0·21	−0·05	35·71
66	Southeast Yolo Base	Cal.	1880	Northwest Yolo Base	163 07 13·25	0·16	−0·14	13·11
67	Northwest Yolo Base	Cal.	1880	Southeast Yolo Base	343 05 02·16	0·13	−0·09	02·07
68	Mount Diablo	Cal.	1876	Mount Helena	144 28 15·86	0·10	+0·17	16·03
69	Vaca	Cal.	1880	Southeast Yolo Base	235 38 36·44	0·27	+0·11	36·55
70	Monticello	Cal.	1880	Mount Helena	91 04 25·28	0·21	+0·02	25·30
71	Mount Tamalpais	Cal.	1882	Mount Diablo	274 15 15·14	0·15	−0·10	15·04
72	Mount Helena	Cal.	1876	Mount Diablo	324 01 25·06	0·13	−0·10	24·96
73	Paxton	Cal.	1897	Mount Sanhedrin	203 47 05·80	±0·18	−0·03	05·77

PART VI.

THE RESULTS OF ASTRONOMIC DETERMINATIONS OF LONGITUDE.

CONTENTS OF PART VI.

VI. THE RESULTS OF THE ASTRONOMIC DETERMINATIONS OF LONGITUDE.

A. INTRODUCTION.

The results of the telegraphic longitude determinations at stations distributed over or near the parallel of 39° and geodetically connected with the transcontinental triangulation are given in the following pages.

The longitudes of the stations in connection with the measurement of the arc of the parallel depend wholly upon the results of the adjustment of the general longitude system of the United States, a full account of which is contained in Appendix No. 2, Report of the Coast and Geodetic Survey for the fiscal year ending June 30, 1897.* Several of the stations are common to both systems, and the abstracts of individual values for difference of longitude for these stations will be found in the above Appendix.

A few of the arc stations are connected with more than one fixed longitude station. For these the results of the simple adjustment are given.†

For particulars respecting methods of arrangements in the field, of instruments, observing and deducing individual and final results the reader may consult Appendix No. 14, Coast and Geodetic Survey Report for 1880, pages 231–241;‡ also (for reduction) Appendix No. 8, Coast and Geodetic Survey Report for 1889, pages 209–212, and (for latest instruments) Appendix No. 9, same report, pages 213–216.

B. ABSTRACTS OF RESULTS AT TELEGRAPHIC LONGITUDE STATIONS.

[The tabular results are given in chronological order of the execution of the work.]

Contents, difference of longitude between—

* An abstract of this paper appeared in No. 412 (September 14, 1897) of Gould's Astronomical Journal.

† No use was made of any longitude work by the United States Engineers within the region of the arc unless the observers exchanged places for the purpose of eliminating personal equation.

‡ A revision of this appendix was published as Appendix No. 7, C. & G. S. Report, 1897–98.

Contents, difference of longitude between—

(1) DIFFERENCE OF LONGITUDE BETWEEN PARKERSBURG, ILLINOIS, AND DETROIT, MICHIGAN.

[Determined by the United States Lake Survey. For particulars see Professional Papers No. 24 of the Corps of Engineers of the United States Army, Washington, 1882; pp. 725-727.]

Date, 1879.	Observer at— Olney.	Observer at— Detroit.	From Western or Olney signals.	From Eastern or Detroit signals.	W—E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	v.
			h. m. s.	*h. m. s.*	*s.*	*h. m. s.*	*s.*	*h. m. s.*	*s.*
July 26	P. M. Price	D. W. Lockwood	0 20 08·582	0 20 08·404	0·178	0 20 08·493	+0·003	0 20 08·496	+·011
28			08·602	08·409	·193	·505		·508	+·023
29			08·645	08·410	·235	·527		·530	+·045
30			08·498	08·308	·190	·403		·406	-·079
				Mean	0·199	0 20 08·482		0 20 08·485	

Transmission time $= 0^s{\cdot}100 \pm 0^s{\cdot}004$.

Personal equation Lockwood-Price $= +0^s{\cdot}003 \pm 0^s{\cdot}036$ from direct observations on 2 days before and 2 days after the longitude work.

Buff and Berger transit, No. 2 of the Lake Survey, was mounted on the East pier in the Lake Survey Observatory at Detroit. By direct measurement in 1891 this pier was found to be $0^s{\cdot}366$ west of the Coast and Geodetic Survey station.

Würdemann transit, No. 1 of the Lake Survey, was mounted at Olney, about 10 miles north of the trigonometrical station Parkersburg. By a local triangulation the transit post was found to be $13^s{\cdot}461$ west of Parkersburg.

$\Delta\lambda$ Parkersburg $\triangle$ — Detroit (T_{1891}) $= 0^h\ 19^m\ 55^s{\cdot}390 \pm 0^s{\cdot}040$.

(2) DIFFERENCE OF LONGITUDE BETWEEN STRASBURG, VIRGINIA, AND WASHINGTON, DISTRICT OF COLUMBIA.

Date, 1881.	Observer at— Strasburg.	Observer at— Washington.	From Western or Strasburg signals.	From Eastern or Washington signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
June 14	E. Smith	G. W. Dean	5 14·252	5 14·249	0·003	5 14·250	−0·142	5 14·108	2	+ ·005
15			·274	·263	·011	·268		·126	2	+ ·023
16			·241	·229	·012	·235		·093	5	− ·010
				Mean	·009	·251				
18	G. W. Dean	E. Smith	5 13·930	5 13·913	·017	5 13·922	+ ·142	·064	2	− ·039
19			13·960	·952	·008	13·956		·098	3	− ·005
21			14·014	·998	·016	14·006		·148	2	+ ·045
				Mean	·014	13·961		5 14·106		
						Weighted mean		5 14·103		± 0·008

Transmission time $= 0^s·006 \pm 0^s·001$.

Personal equation D. -Sm. $= - 0^s·145 \pm 0^s·010$; same from weighted means $= - 0^s·142$.

At Strasburg, transit No. 4 was mounted on a brick pier within the old earthworks to the north of the town.

At Washington, transit No. 8 was mounted over the old station of 1878 in the grounds of the United States Naval Observatory, old site, now the Museum of Hygiene. The station is 44·714 metres or $0^s·124$ *west* of the center of the small central dome of the building.

$\Delta\lambda$ Strasburg (T_{1881})—Washington, United States Naval Observatory, old site (D) $= 5^m\ 14^s·227 \pm 0^s·008$.

(3) DIFFERENCE OF LONGITUDE BETWEEN VINCENNES, INDIANA, AND NASHVILLE, TENNESSEE.

Date. 1881.	Observer at— Vincennes.	Observer at— Nashville.	From Western or Vincennes signals.	From Eastern or Nashville signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Nov. 12	E. Smith	G. W. Dean	2 58·119	2 58·111	0·008	2 58·115	−0·200	2 57·915	6	+ ·024
13			·123	·111	·012	·117		·917	4	+ ·026
14			·073	·048	·025	·060		·860	8	− ·031
				Mean	·015	·097				
16	G. W. Dean	E. Smith	2 57·782	2 57·762	·020	2 57·772	+0·200	972	5	+ ·081
19			·571	·548	·023	·560		·760	3	− ·131
24			·691	·686	·005	·688		·888	8	− ·003
				Mean	·016	·073		2 57·885		
						Weighted mean		2 57·891		±0·018

Transmission time $= 0^s·008 \pm 0^s·001$.

Personal equation D.—Sm. $= - 0^s·212 \pm 0^s·022$; same from weighted means $= - 0^s·200$.

At Vincennes, transit No. 4 was mounted in the Court-House yard, northeast of the Court-House.

At Nashville, transit No. 8 was mounted over the station of 1877, east of the Capitol or State House.

$\Delta\lambda$ Vincennes (T_{1881})—Nashville ($T_{1877-81}$) $= 2^m\ 57^s·891 \pm 0^s·018$.

(4) DIFFERENCE OF LONGITUDE BETWEEN ST. LOUIS, MISSOURI, AND VINCENNES, INDIANA.

Date, 1881.	Observer at— St. Louis.	Observer at— Vincennes.	From Western or St. Louis signals.	From Eastern or Vincennes signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Nov. 28	E. Smith	C. H. Sinclair	10 43·366	10 43·351	0·015	10 43·358	−0·087	10 43·271	5	+·036
Dec. 7			·338	·300	·038	·319		·232	2	−·003
8			·328	·273	·055	·300		·213	5	−·022
9			·309	·275	·034	·292		·205	2	−·030
				Mean	·035	·317				
Dec. 14	C. H. Sinclair	E. Smith	10 43·162	10 43·111	·051	10 43·136	+0·087	·223	4	−·012
16			·187	·142	·045	·164		·251	6	+·016
23			·166	·120	·046	·143		·230	9	−·005
				Mean	·047	·148		10 43·232		
						Weighted mean		10 43·235		±0·006

Transmission time $= 0^s{\cdot}020 \pm 0^s{\cdot}002$.

Personal equation Sm.—Sin. $= + 0^s{\cdot}085 \pm 0^s{\cdot}006$; same from weighted means $= + 0^s{\cdot}087$.

At St. Louis, transit No. 6 was mounted over the station of 1881, in the east end of the small brick observatory attached to Washington University.

At Vincennes, transit No. 4 was mounted in the Court-House yard, northeast of the Court-House.

$\Delta\lambda$ St. Louis ($T_{1881-82}$) - Vincennes (T_{1881}) $= 10^m\ 43^s{\cdot}235 \pm 0^s{\cdot}006$.

(5) DIFFERENCE OF LONGITUDE BETWEEN CHARLOTTESVILLE, VIRGINIA, AND WASHINGTON, DISTRICT OF COLUMBIA.

Date, 1882.	Observer at— Charlottesville.	Observer at— Washington.	From Western or Charlottesville signals.	From Eastern or Washington signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
July 15	C.H.Sinclair	F.H.Parsons	5 53·171	5 53·106	0·065	5 53·138	−0·099	5 53·039	3	−·024
24			·108	·091	·017	·100		·001	3	−·062
25			·235	·219	·016	·227		·128	4	+·065
				Mean	·033	·155				
July 27	F.H.Parsons	C.H.Sinclair	5 52·896	5 52·882	·014	5 52·889	+0·099	52·988	4	−·075
Aug. 7			53·005	53·000	·005	53·002		53·101	4	+·038
10			52·982	52·971	·011	52·976		·075	4	+·012
11			52·987	·984	·003	·986		·085	5	+·022
				Mean	·008	52·963		5 53·060		
						Weighted mean		5 53·063		±0·014

Transmission time $= 0^s{\cdot}009 \pm 0^s{\cdot}003$.

Personal equation Sin. - P. $= + 0^s{\cdot}096 \pm 0^s{\cdot}012$; same from weighted means $= + 0^s{\cdot}099$.

At Charlottesville, transit No. 4 was mounted on the small transit pier on the east side of the large equatorial of McCormick Observatory.

At Washington, transit No. 8 was mounted over the old station of 1878 in the grounds of the United States Naval Observatory, old site, now the Museum of Hygiene. This station is 44·714 metres or $0^s{\cdot}124$ *west* of the center of the small central dome of the building.

$\Delta\lambda$ Charlottesville (T_{1882}) - Washington, United States Naval Observatory, old site (D) $= 5^m\ 53^s{\cdot}187 \pm 0^s{\cdot}014$.

(6) DIFFERENCE OF LONGITUDE BETWEEN LOUISVILLE, KENTUCKY, AND CHARLESTON, WEST VIRGINIA.

Date, 1883.	Observer at— Louisville.	Observer at— Charleston.	From Western or Louisville signals.	From Eastern or Charleston signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Aug. 16	C. Terry	F. H. Parsons	16 31 ·497	16 31 ·415	0 ·082	16 31 ·456	+0 ·049	16 31 ·505	3	− ·001
17			·556	·495	·061	·526		·575	4	+ ·069
21			·517	·450	·067	·483		·532	3	+ ·026
24			·422	·346	·076	·384		·433	2 ·5	− ·073
25			·428	·374	·054	·401		·450	3	− ·056
				Mean	·068	·450				
Aug. 29	F. H. Parsons	C. Terry	16 31 ·636	16 31 ·590	·046	16 31 ·613	−0 ·049	·564	5	+ ·058
30			·460	·412	·048	·436		·387	4	− ·119
31			·583	·521	·062	·552		·503	1 ·5	− ·003
Sept. 3			·604	·545	·059	·574		·525	2 ·5	+ ·019
5			·620	·564	·056	·592		·543	4	+ ·037
				Mean	·054	·553		16 31 ·502		
						Weighted mean		16 31 ·506		±0·015

Transmission time $= 0^s·031 \pm 0^s·001$.

Personal equation T. − P. $= -0^s·052 \pm 0^s·018$; same from weighted means $= -0^s·049$.

At Louisville, transit No. 8 was mounted over the station established in 1879 in the grounds of the Boys' High School.

At Charleston, transit No. 6 was mounted on a sandstone pier in the northwestern part of the State House grounds.

$\Delta\lambda$ Louisville ($T_{1879\ 83}$) − Charleston (T_{1883}) $= 16^m\ 31^s·506 \pm 0^s·015$.

(7) DIFFERENCE OF LONGITUDE BETWEEN ELLSWORTH, KANSAS, AND KANSAS CITY, MISSOURI.

Date, 1885.	Observer at— Ellsworth.	Observer at— Kansas City.	From Western or Ellsworth signals.	From Eastern or Kansas City signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Sept. 10	F. H. Parsons	E. Smith	14 32 ·946	14 32 ·916	0 ·030	14 32 ·931	+0 ·108	14 33 ·039	0 ·5	+ ·059
13			·884	·871	·013	·877		32 ·985	3	+ ·005
14			·866	·833	·033	·850		32 ·958	7 ·5	− ·022
15			·927	·904	·023	·915		33 ·023	3	+ ·043
				Mean	·025	·893				
Sept. 16	E. Smith	F. H. Parsons	14 33 ·082	14 33 ·023	·059	14 33 ·052	−0 ·108	32 ·944	5 ·5	− ·036
17			·053	·034	·019	·044		32 ·936	6 ·5	− ·044
18			·140	·111	·029	·125		33 ·017	4 ·5	+ ·037
19			·165	·141	·024	·153		33 ·045	5	+ ·065
				Mean	·033	·094		14 32 ·993		
						Weighted mean		14 32 ·980		±0·011

Transmission time $= 0^s·014 \pm 0^s·002$.

Personal equation Sm. − P. $= +0^s·100 \pm 0^s·012$; same from weighted means $= +0^s·108$.

At Kansas City, transit No. 8 was mounted over the old station established in 1882 in the grounds of the Franklin School.

At Ellsworth, transit No. 4 was mounted on 2 limestone piers in the grounds of the Graded School, near Douglas avenue and Second street.

$\Delta\lambda$ Ellsworth (T_{1885}) − Kansas City ($T_{1882\text{-}85}$) $= 14^m\ 32^s·980 \pm 0^s·011$.

(8) DIFFERENCE OF LONGITUDE BETWEEN WALLACE, KANSAS, AND ELLSWORTH, KANSAS.

Date, 1885.	Observer at— Wallace.	Observer at— Ellsworth.	From Western or Wallace signals.	From Eastern or Ellsworth signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Sept. 24	F. H. Parsons	E. Smith	13 27·235	13 27·203	0·032	13 27·219	+0·090	13 27·309	2·5	+·041
25			·156	·135	·021	·146		·236	4	−·032
26			·253	·230	·023	·242		·332	2	+·064
29			·169	·153	·016	·161		·251	6·5	−·017
				Mean	·023	·192				
Oct. 1	E. Smith	F. H. Parsons	13 27·345	13 27·325	·020	13 27·335	−0.090	·245	4	−·023
3			·337	·328	·009	·332		·242	6·5	−·026
4			·439	·432	·007	·436		·346	2·5	+·078
5			·386	·374	·012	·380		·290	4	+·022
6			·369	·341	·028	·355		·265	4·5	−·003
				Mean	·015	·368		13 27·280		
						Weighted mean		13 27·268		±0·009

Transmission time $= 0^s{\cdot}009 \pm 0^s{\cdot}001$.

Personal equation Sm. − P. $= + 0^s{\cdot}088 \pm 0^s{\cdot}009$; same from weighted means $= + 0^s{\cdot}090$.

At Wallace, transit No. 6 was mounted on 2 limestone piers in the northeast corner of the small park of the Union Pacific Railroad Company.

At Ellsworth, transit No. 4 was mounted on 2 limestone piers in the grounds of the Graded School, near Douglas avenue and Second street.

$\Delta\lambda$ Wallace (T_{1885}) -- Ellsworth (T_{1885}) $= 13^m\ 27^s{\cdot}268 \pm 0^s{\cdot}009$.

(9) DIFFERENCE OF LONGITUDE BETWEEN COLORADO SPRINGS, COLORADO, AND WALLACE, KANSAS.

Date, 1885.	Observer at— Colorado Springs.	Observer at— Wallace.	From Western or Colorado Springs signals.	From Eastern or Wallace signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude, $\Delta\lambda$.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Oct. 9	F. H. Parsons	E. Smith	12 54·721	12 54·675	0·046	12 54·698	+0·102	12 54·800	3	−·022
12			·743	·716	·027	·730		·832	4	+·010
13			·719	·705	·014	·712		·814	3	−·008
14			·685	·668	·017	·676		·778	3	−·044
15			·785	·768	·017	·776		·878	3	+·056
				Mean	·024	·718				
Oct. 20	E. Smith	F. H. Parsons	12 54·930	12 54·890	·040	12 54·910	−0·102	·808	3	−·014
21			55·165	55·133	·032	55·149		55·047	2	+·225
22			54·893	54·859	·034	54·876		54·774	3	−·048
23			54·806	54·779	·027	54·792		·690	2	−·132
				Mean	·033	54·932		12 54·825		
						Weighted mean		12 54·822		±0·020

Transmission time $= 0^s{\cdot}014 \pm 0^s{\cdot}001$.

Personal equation Sm. − P. $= +0^s{\cdot}107 \pm 0^s{\cdot}021$; same from weighted means $= + 0^s{\cdot}102$.

At Colorado Springs, transit No. 6 was mounted over the new or 1885 station in the grounds of the Colorado Springs Land Company.

At Wallace, transit No. 4 was mounted on 2 limestone piers in the northeast corner of the small park of the Union Pacific Railroad Company.

$\Delta\lambda$ Colorado Springs ($T_{1885\text{-}86}$) — Wallace (T_{1885}) $= 12^m\ 54^s{\cdot}822 \pm 0^s{\cdot}020$.

(10) DIFFERENCE OF LONGITUDE BETWEEN GUNNISON, COLORADO, AND COLORADO SPRINGS, COLORADO.

Date, 1886.	Observer at— Gunnison.	Observer at— Colorado Springs.	From Western or Gunnison signals.	From Eastern or Colorado Springs signals.	W.-E.	Mean of West and East signals.	Personal equations.	Difference of longitude Δλ.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
June 17	E. Smith	C. H. Sinclair	8 25·310	8 25·264	0·046	8 25·287	+0·001	8 25·288	1·5	−·047
18			·355	·315	·040	·335		·336	5·0	+·001
23			·394	·347	·047	·370		·371	4·5	+·036
26			·317	·273	·044	·295		·296	2·5	−·039
				Mean	·044	·322				
June 30	C. H. Sinclair	E. Smith	8 25·341	8 25·298	·043	8 25·320	−0·001	·319	3·5	−·016
July 2			·364	·328	·036	·346		·345	2·0	+·010
3			·367	·328	·039	·348		·347	1·0	+·012
8			·376	·334	·042	·355		·354	1·5	+·019
				Mean	·040	·342		8 25·332		
						Weighted mean		8 25·335		±0·00[illegible]

Transmission time $= 0^s·021 \pm 0^s·001$.

Personal equation Sm. - Sin. $= -0^s·010 \pm 0^s·006$; same from weighted means $= - 0^s·001$.

At Gunnison, transit was mounted on a sandstone pier in the northeast corner of the Court-House grounds.

At Colorado Springs, transit No. 6 was mounted over the new or 1885 station in the grounds of the Colorado Springs Land Company.

$\Delta\lambda$ Gunnison (T_{1886}) — Colorado Springs ($T_{1885\cdot86}$) $= 8^m\ 25^s·335 \pm 0^s·007$.

(11) DIFFERENCE OF LONGITUDE BETWEEN GRAND JUNCTION, COLORADO, AND COLORADO SPRINGS, COLORADO.

Date, 1886.	Observer at— Grand Junction.	Observer at— Colorado Springs.	From Western or Grand Junction signals.	From Eastern or Colorado Springs signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
July 15	C. H. Sinclair	E. Smith	14 58·948	14 58·892	0·056	14 58.920	+0·039	14 58·959	1	+·068
24			·978	931	·047	·954		·993	1	+·102
26			·932	·834	·098	·883		·922	1	+·031
27			·822	·721	·101	·772		811	2·5	−·080
				Mean	·076	·882				
July 30	E. Smith	C. H Sinclair	14 58·963	14 58·875	·088	14 58·919	−0·039	·880	1·5	−·011
31			·986	·902	·084	·944		·905	2	+·014
Aug. 4			·977	·893	·084	·935		·896	2	+·005
5			·957	·873	·084	·91[illegible]		·876	1·5	−·015
				Mean	·085	·928		14 58·905		
						Weighted mean		14 58·891		±0·013

Transmission time $= 0^s·040 \pm 0^s·002$.

Personal equation Sm. Sin. $= + 0^s·023 \pm 0^s·012$; same from weighted means $= + 0^s·039$.

At Grand Junction, transit No. 4 was mounted on 2 stone piers near the northwest corner of Cottonwood Park.

At Colorado Springs, transit No. 6 was mounted over the new or 1885 station in the grounds of the Colorado Springs Land Company.

$\Delta\lambda$ Grand Junction (T_{1886}) — Colorado Springs ($T_{1885\cdot86}$) $= 14^m\ 58^s·891 \pm 0^s·013$.

(12) DIFFERENCE OF LONGITUDE BETWEEN SAN FRANÇISCO, LAFAYETTE PARK, AND SAN FRANCISCO, WASHINGTON SQUARE, CALIFORNIA.

Date, 1887.	Observed at— Lafayette Park.	Observed at— Washington Square.	From Western or Park signals.	From Eastern or Square signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$	p.	v.
			s.	s.	s.	s.	s.	s.		s.
May 26	C. H. Sinclair	P. A. Welker	4·667	4·661	+0·006	4·664	−0·172	4·492	2·5	+·071
27			·598	·590	·008	·594		·422	5·5	+·001
June 3			·618	·617	·001	·617		·445	3·5	+·024
4			·550	·546	·004	·548		·376	7·5	−·045
6			·601	·602	−·001	·602		·430	5·5	+·009
				Mean	+·004	4·605				
June 7	P. A. Welker	C. H. Sinclair	4·271	4·272	−·001	4·271	+0·172	·443	6	+·022
9			·261	·250	+·011	·256		·428	4	+·007
10			·229	·223	+·006	·226		·398	6·5	−·023
12			·248	·248	·000	·248		·420	6	−·001
13			·245	·251	−·006	·248		·420	5·5	−·001
				Mean	+·002	4·250		4·427		
						Weighted mean		4·421		±0·006

Transmission time $= 0^s·0014 \pm 0^s·0005$.

Personal equation S. − W. $= + 0^s·178 \pm 0^s·006$; same from weighted means $= + 0^s·172$.

At the Lafayette Park, San Francisco, transit No. 3 was mounted on the western or standard pier of 1881.

At the Washington Square, San Francisco, transit No. 6 was mounted on the brick pier near the old station of 1869, which was marked by a granite block. The use of the pier of 1887 became necessary since the instrument could not be put on the block; it is $0^m·405$ or $0^s·017$ or $0^s·001$ *east* of the old station.

$\Delta\lambda$ San Francisco, Lafayette Park ($T_{1881-87}$) − San Francisco, Washington Square (T_{1869}) $= 4^s·420 \pm 0^s·006$.

(13) DIFFERENCE OF LONGITUDE BETWEEN SAN FRANCISCO AND MOUNT HAMILTON, CALIFORNIA.*

Date, 1888.	Observers at— San Francisco.	Observers at— Mount Hamilton.	From Western or San Francisco signals.	From Eastern or Mount Hamilton signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Oct. 23	C.H.Sinclair	R. A. Marr	3 09·099	3 09·076	0·023	3 09·088	−0·140	3 08·948	9	−·099
30			·180	·148	·032	·164		09·024	9·5	−·023
31			·138	·128	·010	·133		08·993	6	−·054
Nov. 1			·263	·259	·004	·261		09·121	7	+·074
2			·221	·213	·008	·217		09·077	6	+·030
5			·248	·244	·004	·246		09·106	12	+·059
				Mean	·014	3 09·185				
Nov. 23	R. A. Marr	C.H.Sinclair	3 08·899	3 08·894	·005	3 08·896	+0·140	09·036	2	−·011
24			·885	·864	·021	·874		09·014	2·5	−·033
26			·953	·935	·018	·944		09·084	5	+·037
27			·910	·902	·008	·906		09·046	2	−·001
28			·875	·857	·018	·866		09·006	2	−·041
				Mean	·014	3 08·898		3 09·041		
						Weighted mean		3 09·047		±0·013

Transmission time $= 0^s·007 \pm 0^s·001$.

Personal equation S. − M. $= + 0^s·144 \pm 0^s·011$; same from weighted means $= + 0^s·140$.

At San Francisco, transit No. 18 was mounted on the eastern or small transit pier in the Lafayette Park Observatory. Reduction to western transit pier (of 1881) $0^s·004$.

At Mount Hamilton, transit No. 19 was mounted about a quarter of a mile to the eastward of the Lick Observatory. Reduction to meridian of transit house $16''·281$, or $1^s·085$.

$\Delta\lambda$ San Francisco, Lafayette Park ($T_{1881-87}$) − Mount Hamilton, Lick Observatory (Transit house) $3^m\ 07^s·966 \pm 0^s·013$.

* For a more detailed account of this work see Appendix No. 8, Coast and Geodetic Survey Report for 1889, or Bulletin No. 13, 1889; the latest result is given in Appendix No. 2, Coast and Geodetic Survey Report for 1897, p. 260.

(14) DIFFERENCE OF LONGITUDE BETWEEN POINT ARENA, CALIFORNIA, AND SAN FRANCISCO, CALIFORNIA.

Date, 1889.	Observer at— Point Arena.	Observer at— San Francisco.	From Western or Point Arena signals.	From Eastern or San Francisco signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Jan. 16	R. A. Marr	C. H. Sinclair	5 04 ·050	5 04 ·016	0 ·034	5 04 ·033	+0 ·237	5 04 ·270	2	+ ·020
18			03 ·993	03 ·935	·058	03 ·964		·201	5·5	− ·049
19			04 ·002	03 ·969	·033	03 ·985		·222	4	− ·028
19			·031	03 ·990	·041	04 ·010		·247	3	− ·003
21			·044	04 ·007	·037	·026		·263	5·5	+ ·013
22			·073	04 ·027	·046	·050		·287	8	+ ·037
				Mean	·042	04 ·011				
Jan. 25	C. H. Sinclair	R. A. Marr	5 04 ·470	5 04 ·424	·046	5 04 ·447	−0 ·237	·210	2	− ·040
26			·456	·415	·041	·436		·199	5	− ·051
26			·436	·400	·036	·418		·181	3	− ·069
27			·546	·514	·032	·530		·293	5	+ ·043
28			·531	·503	·028	·517		·280	7	+ ·030
29			·533	·489	·044	·511		·274	5	+ ·024
				Mean	·038	·477		5 04 ·244		
						Weighted mean		5 04 ·250		±0 ·000

Transmission time $= 0^s{\cdot}020 \pm 0^s{\cdot}001$.

Personal equation Sin. — M. $= +0^s{\cdot}233 \pm 0^s{\cdot}005$; same from weighted means $= +0^s{\cdot}237$.

At Point Arena, transit No. 19 was mounted on a brick pier upon a hill about 200 metres east of the Main street of the town, between 2 large water tanks.

At San Francisco, transit No. 18 was mounted on the eastern or small pier in the Lafayette Park Observatory. It was 62 inches ($0^s{\cdot}004$) east of the western or standard pier.

$\Delta\lambda$ Point Arena (T_{1889}) — San Francisco, Lafayette Park ($T_{1881\text{-}87}$) $= 5^m\ 04^s{\cdot}246 \pm 0^s{\cdot}008$.

(15) DIFFERENCE OF LONGITUDE BETWEEN POINT ARENA, CALIFORNIA, AND SACRAMENTO, CALIFORNIA.

Date, 1889.	Observer at— Point Arena.	Observer at— Sacramento.	From Western or Point Arena signals.	From Eastern or Sacramento signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Jan. 31	C. H. Sinclair	R. A. Marr	8 48 ·965	8 48 ·856	0 ·109	8 48 ·910	−0 ·222	8 48 ·688	7	+ ·013
Feb. 1			·910	·818	·092	·864		·642	9	− ·033
2			·977	·871	·106	·924		·702	6	+ ·027
2			·999	·932	·067	·966		·744	3	+ ·069
3			·915	·830	·085	·872		·650	7	− ·025
				Mean	·092	·907				
Feb. 7	R. A. Marr	C. H. Sinclair	8 48 ·510	8 48 ·429	·081	8 48 ·470	+0 ·222	·692	4	+ ·017
8			·482	·419	·063	·450		·672	4	− ·003
8			·522	·465	·057	·494		·716	3	+ ·041
9			·483	·394	·089	·438		·660	5	− ·015
12			·467	·394	·073	·430		·652	5	− ·023
				Mean	·073	·456		8 48 ·682		
						Weighted mean		8 48.675		±0 ·007

Transmission time $= 0^s{\cdot}041 \pm 0^s{\cdot}002$.

Personal equation Sin. — M. $= +0^s{\cdot}225 \pm 0^s{\cdot}007$; same from weighted means $= +0^s{\cdot}222$.

At Point Arena, transit No. 19 was mounted on a brick pier upon a hill about 200 metres east of the main street of the town, between 2 large water tanks.

At Sacramento, transit No. 18 was mounted on the granite block pier of 1888, in the grounds of the Capitol, on the east side of the building.

$\Delta\lambda$ Point Arena (T_{1889}) — Sacramento ($T_{1888\text{-}89}$) $= 8^m\ 48^s{\cdot}675 \pm 0^s{\cdot}007$.

(16) DIFFERENCE OF LONGITUDE BETWEEN MARYSVILLE, CALIFORNIA, AND SACRAMENTO, CALIFORNIA.

Date, 1889.	Observer at— Marysville.	Observer at— Sacramento.	From Western or Marysville signals.	From Eastern or Sacramento signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Feb. 26	R. A. Marr	C. H. Sinclair	0 22·621	0 22·621	0·000	0 22·621	+0·266	0 22·887	4	+·088
27			·499	·512	−·013	·506		·772	6	−·027
28			·518	·516	+·002	·517		·783	4	−·016
28			·555	·554	+·001	·554		·820	4	+·021
Mar. 1			·518	·531	−·013	·524		·790	6	−·009
2			·469	·482	−·013	·476		·742	3	−·057
				Mean	−·006	·533				
Mar. 3	C. H. Sinclair	R. A. Marr	0 23·062	0 23·057	+·005	0 23·060	−0·266	·794	4	−·005
4			·062	·075	−·013	·069		·803	4	+·004
5			·081	·077	+·004	·079		·813	2	+·014
5			·079	·074	+·005	·077		·811	6	+·012
6			·054	·044	+·010	·049		·783	6	−·016
				Mean	+·002	·067		0 22·800		
						Weighted mean		0 22·799		±0·007

Transmission time very nearly zero.

Personal equation Sin. = M. = $+0^{s}{\cdot}267 \pm 0^{s}{\cdot}007$; same from weighted means $= + 0^{s}{\cdot}266$.

At Marysville, transit No. 19 was mounted on a brick pier in Cortez square, one block east of the Court-House.

At Sacramento, transit No. 18 was mounted on the granite block pier of 1888 in the grounds of the Capitol, on the east side of the building.

$\Delta\lambda$ Marysville (T_{1889}) − Sacramento ($T_{1888\text{-}89}$) $= 0^{m}\ 22^{s}{\cdot}799 \pm 0^{s}{\cdot}007$.

(17) DIFFERENCE OF LONGITUDE BETWEEN SACRAMENTO, CALIFORNIA, AND VERDI, NEVADA.

Date, 1889.	Observer at— Sacramento.	Observer at— Verdi.	From Western or Sacramento signals.	From Eastern or Verdi signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
June 24	C. H. Sinclair	R. A. Marr	6 03·168	6 03·149	0·019	6 03·158	−0·244	6 02·914	5	+·048
25			·137	·115	·022	·126		·882	4	+·016
28			·105	·093	·012	·099		·855	7	−·011
29			·083	·063	·020	·073		·829	6	−·037
				Mean	·018	·114				
July 1	R. A. Marr	C. H. Sinclair	6 02·628	6 02·618	·010	6 02·623	+0·244	·867	8	+·001
2			·645	·622	·023	·633		·877	9	+·011
3			·597	·582	·015	·590		·834	6	−·032
4			·648	·634	·014	·641		·885	5	+·019
				Mean	·016	·622		6 02·868		
						Weighted mean		6 02·866		±0·007

Transmission time $= 0^{s}{\cdot}008 \pm 0^{s}{\cdot}001$.

Personal equation Sin. − M. = $+ 0^{s}{\cdot}246 \pm 0^{s}{\cdot}007$; same from weighted means $= + 0^{s}{\cdot}244$.

At Sacramento, transit No. 18 was mounted on the granite block pier of 1888 in the grounds of the Capitol, on the east side of the building.

At Verdi, transit No. 18 was mounted on a brick pier built on a slight elevation back of Mr. O. Lonkey's residence, about one-third of a mile east of the central part of the town.

$\Delta\lambda$ Sacramento ($T_{1888\text{-}89}$) − Verdi (T_{1889}) $= 6^{m}\ 02^{s}{\cdot}866 \pm 0^{s}{\cdot}007$.

(18) DIFFERENCE OF LONGITUDE BETWEEN VERDI, NEVADA, AND CARSON CITY, NEVADA.

Date, 1889.	Observer at— Verdi.	Observer at— Carson City.	From Western or Verdi signals.	From Eastern or Carson City signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
July 6	R. A. Marr	C. H. Sinclair	0 52·870	0 52·858	0·012	0 52·864	−0·273	0 52·591	4	+·031
7			·893	·878	·015	·886		·613	3	+·053
9			·828	·817	·011	·822		·549	7	−·011
10			·773	·765	·008	·769		·496	3	−·064
				Mean	·012	·835				
July 11	C. H. Sinclair	R. A. Marr	0 52·236	0 52·225	·011	0 52·230	+0·273	·503	4	−·057
12			·319	·304	·015	·312		·585	3	+·025
13			·311	·297	·014	·304		·577	7	+·017
14			·290	·268	·022	·279		·552	7	−·008
16			·308	·290	·018	·299		·572	8	+·012
				Mean	·016	·285		0 52·560		
						Weighted mean		0 52·560		±0·008

Transmission time $= 0^s·007 + 0^s·000\ 4$.

Personal equation Sin. — M. $= +0^s·275 \pm 0^s·008$; same from weighted means $= +0^s·273$.

At Verdi, transit No. 19 was mounted on a brick pier built on an elevation back of Mr. O. Lonkey's residence, about one-third of a mile east of the central part of the town.

At Carson City, transit No. 18 was mounted on the transit pier in Mr. Charles W. Friend's observatory, near the corner of King and Stewart streets.

$\Delta\lambda$ Verdi (T_{1889}) — Carson City, Friend's observatory (T_{1889}) $= 0^m\ 52^s·560 \pm 0^s·008$.

(19) DIFFERENCE OF LONGITUDE BETWEEN CARSON CITY, NEVADA, AND VIRGINIA CITY, NEVADA.

Date, 1889.	Observer at— Carson City.	Observer at— Virginia City.	From Western or Carson City signals.	From Eastern or Virginia City signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
July 19	C. H. Sinclair	R. A. Marr	0 28·467	0 28·468	−0·001	0 28·467	−0·267	0 28·200	5	+·032
20			·416	·423	−·007	·420		·153	6	−·015
21			·403	·408	−·005	·406		·139	6	−·029
22			·449	·456	−·007	·452		·185	6	+·017
				Mean	−·005	·436				
July 23	R. A. Marr	C. H. Sinclair	0 27·906	0 27·911	−·005	0 27·909	+0·267	·176	10	+·008
24			·934	·941	−·007	·937		·204	4	+·036
25			·871	·869	+·002	·870		·137	8	−·031
26			·911	·907	+·004	·909		·176	5	+·008
				Mean	−·002	·906		0 28·171		
						Weighted mean		0 28·168		±0·006

Transmission time very nearly zero.

Personal equation Sin. — M. $= +0^s·265 + 0^s·005$; same from weighted means $= +0^s·267$.

At Carson City, transit No. 18 was mounted on the transit pier in Mr. Charles W. Friend's observatory, near the corner of King and Stewart streets.

At Virginia City, the station was located in the office yard of the "Consolidated California and Virginia Mines," directly opposite the depot of the Virginia and Truckee Railroad. Transit No. 19 was used.

$\Delta\lambda$ Carson City, Friend's Observatory (T_{1889}) — Virginia City (T_{1889}) $= 0^m\ 28^s·168 \pm 0^s·006$.

(20) DIFFERENCE OF LONGITUDE BETWEEN GENOA, NEVADA, AND CARSON CITY, NEVADA.

Date, 1889.	Observer at— Genoa.	Observer at— Carson City.	From Western or Genoa signals.	From Eastern or Carson signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	*p.*	*v.*
			m. s.	*m. s.*	*s.*	*m. s.*	*s.*	*m. s.*		*s.*
July 30	C. H. Sinclair	R. A. Marr	0 18·791	0 18·795	−0·004	0 18·793	−0·223	0 18·570	4−	+·054
31			·770	·765	+ ·005	·768		·545	4	+·029
Aug. 1			·687	·682	+ ·005	·684		·461	5	−·055
2			·724	·731	− ·007	·727		·504	4	−·012
				Mean	0·000	·743				
Aug. 3	R. A. Marr	C. H. Sinclair	0 18·235	0 18·227	+ ·008	0 18 ·231	+0·223	·454	3	−·062
4			·280	·267	+ ·013	·274		·497	7	−·019
5			·310	271	+ ·039	·290		·513	1	−·003
10			·355	·361	− ·006	·358		·581	5	+·065
				Mean	+ ·014	·288		0 18·516		
						Weighted mean		0 18·516		±0·012

Transmission time variable on account of changes in the length of the circuit. For the 5 days, August 1, 2, 3, 4, 5, it was $0^s{\cdot}006$.

Personal equation Sin. − M. = $+0^s{\cdot}228 \pm 0^s{\cdot}015$; same from weighted means = $+0^s{\cdot}223$.

At Genoa, transit No. 19 was mounted on a stone and brick pier in the vacant lot back of the store of Mr. Morris Harris.

At Carson City, transit No. 18 was mounted on the transit pier in Mr. Charles W. Friend's observatory, near the corner of King and Stewart streets.

$\Delta\lambda$ Genoa (T_{1889}) − Carson City, Friend's Observatory (T_{1889}) = $0^m\ 18^s{\cdot}516 \pm 0^s{\cdot}012$.

(21) DIFFERENCE OF LONGITUDE BETWEEN CARSON CITY, NEVADA, AND AUSTIN, NEVADA.

Date, 1889.	Observer at— Carson City.	Observer at— Austin.	From Western or Carson signals.	From Eastern or Austin signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	*p.*	*v.*
			m. s.	*m. s.*	*s.*	*m. s.*	*s.*	*m. s.*		*s.*
Aug. 18	C. H. Sinclair	R. A. Marr	10 45·512	10 45·458	0·054	10 45·485	−0·291	10 45·194	13	+·026
19			·503	·447	·056	·475		·184	7	+·016
20			·413	·363	·050	·388		·097	6	−·071
21			·496	·411	·085	·454		·163	5	−·005
				Mean	·061	·450				
Aug. 24	R. A. Marr	C. H. Sinclair	10 44·999	10 44·928	·071	10 44·964	+0·291	·255	5	+·087
25			·872	·804	·068	·838		·129	5	−·039
26			·893	·796	·097	·844		·135	7	−·033
				Mean	·079	·882		10 45·165		
						Weighted mean		10 45·168		±0·014

Transmission time = $0^s{\cdot}034 \pm 0^s{\cdot}002$.

Personal equation Sin. − M. = $+0^s{\cdot}284 \pm 0^s{\cdot}008$; same from weighted means = $+0^s{\cdot}291$.

At Carson City, transit No. 18 was mounted on the transit pier in Mr. Charles W. Friend's observatory, near the corner of King and Stewart streets.

At Austin, transit No. 19 was used. The station was just west of the Court-House.

$\Delta\lambda$ Carson City, Friend's Observatory (T_{1889}) − Austin (T_{1889}) = $10^m\ 45^s{\cdot}168 \pm 0^s{\cdot}014$.

(22) DIFFERENCE OF LONGITUDE BETWEEN AUSTIN, NEVADA, AND EUREKA, NEVADA.

Date, 1889.	Observer at— Austin.	Observer at— Eureka.	From Western or Austin signals.	From Eastern or Eureka signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. *s.*	*m.* *s.*	*s.*	*m.* *s.*	*s.*	*m.* *s.*		*s.*
Aug. 30	C. H. Sinclair	R. A. Marr	4 27·598	4 27·561	0·037	4 27·579	−0·223	4 27·356	2	+ ·038
Sept. 1			·531	·501	·030	·516		·293	7	− ·025
2			·561	·531	·030	·546		·323	6	+ ·005
3			·571	·533	·038	·552		·329	6	+ ·011
				Mean	·034	·548				
Sept. 5	R. A. Marr	C. H. Sinclair	4 27·088	4 27·071	·017	4 27·080	+0·223	·303	8	− ·015
6			·085	·058	·027	·072		·295	6	− ·023
7			·142	·116	·026	129		·352	7	+ ·034
8			·120	·084	·036	·102		·325	6	+ ·007
				Mean	·026	·096		4 27·322		
						Weighted mean		4 27·318		± 0·006

Transmission time = 0ˢ·015 ± 0ˢ·001.

Personal equation Sin. — M. = + 0ˢ·226 ± 0ˢ·006; same from weighted means = + 0ˢ·223.

At Austin, transit No. 19 was mounted on a brick pier just west of the Court-House.

At Eureka, transit No. 18 was mounted at the station on the east side of the town, near the east end of Bateman street.

$\Delta\lambda$ Austin (T_{1889}) — Eureka (T_{1889}) = $4^m\ 27^s{\cdot}318 \pm 0^s{\cdot}006$.

(23) DIFFERENCE OF LONGITUDE BETWEEN EUREKA, NEVADA, AND SALT LAKE CITY, UTAH.

Date, 1889.	Observer at— Eureka.	Observer at— Salt Lake.	From Western or Eureka signals.	From Eastern or Salt Lake signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude $\Delta\lambda$.	p.	v.
			m. *s.*	*m.* *s.*	*s.*	*m.* *s.*	*s.*	*m.* *s.*		*s.*
Sept. 10	C. H. Sinclair	R. A. Marr	16 15·623	16 15·565	0·058	16 15·594	−0·261	16 15·333	6	− ·004
11			·694	·596	·098	·645		·384	4	+ ·047
12			·620	·530	·090	·575		·314	6	− ·023
14			·647	·540	·107	·594		·333	5	− ·004
				Mean	·088	·602				
Sept. 21	R. A. Marr	C. H. Sinclair	16 15·067	16 15·004	·063	16 15·035	+0·261	·296	9	− ·041
23			·167	·083	·084	·125		·386	5	+ ·049
24			·172	·068	·104	·120		·381	4	+ ·044
25			·113	·017	·096	·065		·326	4	− ·011
				Mean	·087	·086		16 15·344		
						Weighted mean		16 15·337		± 0·009

Transmission time = 0ˢ·044 ± 0ˢ·002.

Personal equation Sin. — M. = + 0ˢ·258 ± 0ˢ·007; same from weighted means = + 0ˢ·261.

At Eureka, transit No. 18 was mounted at the station on the east side of the town, near the east end of Bateman street.

At Salt Lake City, transit No. 19 stood over the old station pier established in 1869 in Temple block.

$\Delta\lambda$ Eureka (T_{1889}) — Salt Lake City ($T_{1869-98}$) = $16^m\ 15^s{\cdot}337 \pm 0^s{\cdot}009$.

(24) DIFFERENCE OF LONGITUDE BETWEEN LAKE TAHOE, CALIFORNIA, AND CARSON CITY, NEVADA.

Date, 1893.	Observer at— Lake Tahoe.	Observer at— Carson City.	From Western or Lake Tahoe signals.	From Eastern or Carson City signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Aug. 3	C. H. Sinclair	G. Davidson	0 44 ·432	0 44 ·431	0 ·001	0 44 ·432	−0 ·358	0 44 ·074	3	− ·035
4			·496	·493	·003	·494		·136	3	+ ·027
6			·482	·473	·009	·478		·120	7	+ ·011
7			·476	·476	·000	·476		·118	4	+ ·009
8			·447	·436	·011	·441		·0833		− ·026
				Mean	·005	·464				
Aug. 9	G. Davidson	C. H. Sinclair	0 43 ·794	0 43 ·785	·009	0 43 ·789	+0 ·358	·147	4	+ ·038
11			·739	·732	·007	·735		·093	6	− ·016
12			·748	·741	·007	·744		·102	9	− ·007
				Mean	·008	·756		0 44 ·109		
						Weighted mean		0 44 ·109		±0 ·006

Transmission time = 0s·003 ± 0s·000 5.

Personal equation Da. — Sin. = − 0s·354 ± 0s·006; same from weighted means = − 0s·358.

At Lake Tahoe, transit No. 18 was mounted on a brick pier on the east side of the road from Bijou to Glenbrook, near the Lake Side Tavern, at the southeast end of the lake.

At Carson City, transit No. 19 was mounted on the latitude pier of 1889 at Mr. Friend's observatory. This pier was 8·015 metres = 0s·022 *east* of the transit pier in the observatory, which was used for longitude work in 1889.

$\Delta\lambda$ Lake Tahoe, southeast end (T_{1893}) — Carson City, Friend's Observatory (T_{1889}) = 44s·087 ± 0s·006.

(25) DIFFERENCE OF LONGITUDE BETWEEN SAN FRANCISCO, PRESIDIO, AND SAN FRANCISCO, LAFAYETTE PARK, CALIFORNIA.

Date, 1896.	Observer at— Presidio.	Observer at— Lafayette Park.	From Western or Presidio signals.	From Eastern or Lafayette Park signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Nov. 11	O. B. French	F. Morse	0 05 ·945	0 05 ·946	−0 ·001	0 05 ·946	+0 ·040	0 05 ·986	5	+ ·034
12			·943	·943	·000	·943		·983	8	+ ·031
13			·877	·879	− ·002	·878		·918	4	− ·034
14			·931	·929	+ ·002	·930		·970	4	+ ·018
20			·842	·843	− ·001	·842		·882	5	− ·070
				Mean	·000	·908				
Nov. 25	F. Morse	O. B. French	0 06 ·008	0 06 ·009	− ·001	0 06 ·008	−0 ·040	·968	3	+ ·016
27			05 ·964	05 ·967	− ·003	05 ·966		·926	4	− ·026
28			05 ·984	05 ·987	− ·003	05 ·986		·946	10	− ·006
29			06 ·003	05 ·998	+ ·005	06 ·000		·960	5	+ ·008
30			06 ·013	06 ·013	·000	06 ·013		·973	4	+ ·021
				Mean	·000	05 ·995		0 05 ·951		
						Weighted mean		0 05 ·952		±0 ·007

Transmission time = 0s·000 ± 0s·000 3.

Personal equation Mo. — Fr. = + 0s·043 ± 0s·008; same from weighted means = + 0s·040.

The Presidio station was established in 1896 in the Presidio Military Reservation. Transit No. 3 was mounted on the west pier in the frame observatory.

At Lafayette Park, transit No. 4 was mounted on the western or standard pier of 1881.

$\Delta\lambda$ San Francisco, Presidio ($T_{1896-97}$) — San Francisco, Lafayette Park ($T_{1881-87}$) = 5s·952 ± 0s·007.

(26) DIFFERENCE OF LONGITUDE BETWEEN WASHINGTON, DISTRICT OF COLUMBIA, AND DOVER, DELAWARE.

Date, 1897.	Observer at— Coast and Geodetic Survey Office.	Observer at— Dover.	From Western or Coast and Geodetic Survey Office signals.	From Eastern or Dover signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	*p*.	*v*.
			m. s.	*m. s.*	*s.*	*m. s.*	*s.*	*m. s.*		*s.*
May 7	C. H. Sinclair	O. B. French	5 56·818	5 56·722	0·096	5 56·770	−0·251	5 56·519	5	+·040
8			·781	·679	·102	·730		·479	8	·000
9			·812	·710	·102	·761		·510	4	+·031
15			·683	·619	·064	·651		·400	4	−·079
				Mean	·091	·728				
May 17	O. B. French	C. H. Sinclair	5 56·240	5 56·181	·059	5 56·210	+0·251	·461	3	−·018
18			·288	·209	·079	·249		·500	4	+·021
19			·240	·177	·063	·209		·460	6	−·019
20			·271	·210	·061	·240		·491	7	+·012
				Mean	·065	·227		5 56·478		
							Weighted mean	5 56·479		±0·009

Transmission time with repeater $= 0^s·047 \pm 0^s·002$.

Transmission time without repeater $= 0^s·031 \pm 0^s·001$.

Personal equation Sin.—Fr. $= +0^s·251 \pm 0^s·012$; same from weighted means $= +0^s·251$.

At Washington, the station of the Coast and Geodetic Survey Office was used. Transit No. 19 was mounted on the east pier, in the small wooden observatory, in the lot south of the office building.

At Dover, transit No. 18 was mounted on a brick pier in a lot just east of and adjoining the Court-House.

$\Delta\lambda$ Washington, Coast and Geodetic Survey Office ($T_{1896-97}$) — Dover (T_{1897}) $= 5^m\ 56^s·479 \pm 0^s·009$.

(27) DIFFERENCE OF LONGITUDE BETWEEN UKIAH, CALIFORNIA, AND SAN FRANCISCO, PRESIDIO, CALIFORNIA.

Date, 1897.	Observer at— Ukiah.	Observer at— San Francisco.	From Western or Ukiah signals.	From Eastern or San Francisco signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	*p*.	*v*.
			m. s.	*m. s.*	*s.*	*m. s.*	*s.*	*m. s.*		*s.*
Nov. 17	C. H. Sinclair	H. P. Ritter	3 01·725	3 01·701	0·024	3 01·713	−0·340	3 01·373	1	−·048
23			·870	·802	·068	·836		·496	1	+·075
25			·783	·757	·026	·770		·430	1	+·009
27			·740	·705	·035	·722		·382	1	−·039
				Mean	·038	·760				
Dec. 1	H. P. Ritter	C. H. Sinclair	3 01·084	3 01·061	·023	3 01·072	+0·340	·412	1	−·009
2			·137	·102	·035	·120		·460	1	+·039
3			·068	·034	·034	·051		·391	1	−·030
				Mean	·031	·081		3 01·421		
							Weighted mean	3 01·421		±0·013

Transmission time $= 0^s·017 \pm 0^s·002$.

Personal equation Sin.—R. $= +0^s·340 \pm 0^s·009$; same from weighted means.

The Presidio station was established in 1896 in the Presidio Military Reservation. Transit No. 3 was mounted on the west pier, in the frame observatory.

At Ukiah, transit No. 4 was mounted on a brick pier, near the southeast corner of the lumber yard of F. M. Mason. It was $105^m·20$ south, and $36^m·99$ (or $0^s·100$) *west* of the flagstaff on the Court-House cupola.

$\Delta\lambda$ Ukiah (T_{1897}) — San Francisco, Presidio ($T_{1896-97}$) $= 3^m\ 01^s·421 \pm 0^s·013$.

(28) DIFFERENCE OF LONGITUDE BETWEEN SALT LAKE CITY AND GREEN RIVER, UTAH.

Date, 1898.	Observer at— Salt Lake.	Observer at— Green River.	From Western or Salt Lake signals.	From Eastern or Green River signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Aug. 1	F. Morse	C. H. Sinclair	6 55·440	6 55·417	0·023	6 55·428	+0·213	6 55·641	3	+·007
2			·467	·426	·041	·447		·660	4	+·026
8			·403	·381	·022	·392		·605	5	−·029
9			·447	·402	·045	·424		·637	6	+·003
				Mean	·033	·423				
Aug. 13	C. H. Sinclair	F. Morse	6 55·866	6 55·834	·032	6 55·850	−0·213	·637	6	+·003
14			·845	·779	·066	·812		·599	7	−·035
16			·905	·863	·042	·884		·671	4	+·037
17			·884	·838	·046	·861		·648	5	+·014
				Mean	·047	·852		6 55·637		
						Weighted mean		6 55·634		±0·006

Transmission time $= 0^s{\cdot}020 \pm 0^s{\cdot}002$.

Personal equation Sin.—Mo. $= + 0^s{\cdot}215 \pm 0^s{\cdot}009$; same from weighted means $= + 0^s{\cdot}213$.

At Salt Lake City, transit No. 18 stood over the old station pier established in 1869, in Temple block.

At Green River, transit No. 19 was mounted on a brick pier west of the depot, on land belonging to the railroad company.

$\Delta\lambda$ Salt Lake City ($T_{1869\text{-}98}$) — Green River (T_{1898}) $= 6^m\ 55^s{\cdot}634 \pm 0^s{\cdot}006$.

(29) DIFFERENCE OF LONGITUDE BETWEEN OASIS AND SALT LAKE CITY, UTAH.

Date, 1898.	Observer at— Oasis.	Observer at— Salt Lake.	From Western or Oasis signals.	From Eastern or Salt Lake signals.	W.-E.	Mean of West and East signals.	Personal equation.	Difference of longitude Δλ.	p.	v.
			m. s.	m. s.	s.	m. s.	s.	m. s.		s.
Aug. 1	F. Morse	C. H. Sinclair	2 56·330	2 56·307	0·023	2 56·318	+0·211	2 56·529	4	+·008
28			·327	·295	·032	·311		·522	4	+·001
30			·373	·349	·024	·361		·572	4	+·051
31			·291	·262	·029	·277		·488	7	−·033
				Mean	·027	·317				
Sept. 1	C. H. Sinclair	F. Morse	2 56·752	2 56·727	·025	2 56·740	−0·211	·529	5	+·008
2			·756	·731	·025	·743		·532	5	+·011
3			·732	·706	·026	·719		·508	4	−·013
4			·739	·712	·027	·726		·515	6	−·006
				Mean	·026	·732		2 56·524		
						Weighted mean		2 56·521		±0·006

Transmission time $= 0^s{\cdot}013 \pm 0^s{\cdot}001$.

Personal equation Sin.—Mo. $= + 0^s{\cdot}208 \pm 0^s{\cdot}007$; same from weighted means $= + 0^s{\cdot}211$.

At Oasis, transit No. 19 was mounted on a brick pier southwest of the depot.

At Salt Lake City, transit No. 18 was mounted over the old station in Temple block, established in 1869.

$\Delta\lambda$ Oasis (T_{1898}) — Salt Lake City ($T_{1869\text{-}98}$) $= 2^m\ 56^s{\cdot}521 \pm 0^s{\cdot}006$.

C. SYNOPSIS OF OBSERVED DIFFERENCES OF LONGITUDE.

No.	Year.	Month.	Western station.	Reference.	Eastern station.	Reference.	Observed difference of longitude.		Probable error.	Reciprocal of weight.
							m.	s.	s.	
1	1879	July	Parkersburg, Ill.	△	Detroit, Mich.	Tr.	19	55·390	±0·040	16
2	1881	June	Strasburg, Va.	Tr.	Washington, D. C.	Dome, old site	5	14·227	·008	1
3	1881	Nov.	Vincennes, Ind.	Tr.	Nashville, Tenn.	Tr.	2	57·891	·018	3
4	1881	Nov. and Dec.	Saint Louis, Mo.	Tr. 1882	Vincennes, Ind.	Tr.	10	43·235	·006	1
5	1882	July and Aug.	Charlottesville, Va.	Tr.	Washington, D. C.	Dome, old site	5	53·187	·014	2
6	1883	Aug. and Sept.	Louisville, Ky.	Tr.	Charleston, W. Va.	Tr.	16	31·506	·015	2
7	1885	Sept.	Ellsworth, Kans.	Tr.	Kansas City, Mo.	Tr.	14	32·980	·011	1
8	1885	Sept. and Oct.	Wallace, Kans.	Tr.	Ellsworth, Kans.	Tr.	13	27·268	·009	1
9	1885	Oct.	Colorado Springs, Colo.	Tr.	Wallace, Kans.	Tr.	12	54·822	·020	4
10	1886	June and July	Gunnison, Colo.	Tr.	Colorado Springs, Colo.	Tr.	8	25·335	·007	1
11	1886	July and Aug.	Grand Junction, Colo.	Tr.	Colorado Springs, Colo.	Tr.	14	58·891	·013	2
12	1887	May and June	San Francisco, Cal.	L. P.	San Francisco, Cal.	W. Sq.	0	04·420	·006	1
13	1888	Oct. and Nov.	San Francisco, Cal.	L. P.	Mount Hamilton, Cal.	Obsy.	3	07·966	·013	2
14	1889	Jan.	Point Arena, Cal.	Tr.	San Francisco, Cal.	L. P.	5	04·246	·008	1
15	1889	Jan. and Feb.	Point Arena, Cal.	Tr.	Sacramento, Cal.	Tr.	8	48·675	·007	1
16	1889	Feb. and Mar.	Marysville, Cal.	Tr.	Sacramento, Cal.	Tr.	0	22·799	·007	1
17	1889	June and July	Sacramento, Cal.	Tr.	Verdi, Nev.	Tr.	6	02·866	·007	1
18	1889	July	Verdi, Nev.	Tr.	Carson City, Nev.	Tr. 1889	0	52·560	·008	1
19	1889	July	Carson City, Nev.	Tr. 1889	Virginia City, Nev.	Tr.	0	28·168	·006	1
20	1889	July and Aug.	Genoa, Nev.	Tr.	Carson City, Nev.	Tr. 1889	0	18·516	·012	1
21	1889	Aug.	Carson City, Nev.	Tr. 1889	Austin, Nev.	Tr.	10	45·168	·014	2
22	1889	Aug. and Sept.	Austin, Nev.	Tr.	Eureka, Nev.	Tr.	4	27·318	·006	1
23	1889	Sept.	Eureka, Nev.	Tr.	Salt Lake City, Utah.	Tr.	16	15·337	·009	1
24	1893	Aug.	Lake Tahoe, SE., Cal.	Tr.	Carson City, Nev.	Tr. 1889	0	44·087	·006	1
25	1896	Nov.	San Francisco, Cal.	Presidio	San Francisco, Cal.	L. P.	0	05·952	·007	1
26	1897	May	Washington, D. C.	Office	Dover, Del.	Tr.	5	56·479	·009	1
27	1897	Nov. and Dec.	Ukiah, Cal.	Tr.	San Francisco, Cal.	Presidio	3	01·421	·013	2
28	1898	Aug.	Salt Lake City, Utah.	Tr.	Green River, Utah	Tr.	6	55·634	·006	1
29	1898	Aug. and Sept.	Oasis, Utah.	Tr.	Salt Lake City, Utah.	Tr.	2	56·521	·006	1

In the above measures there are 4 independent conditions to be satisfied. Vincennes connects with 2 stations whose longitudes were fixed by the adjustment of the longitude net (Appendix No. 2, Report for 1897). Point Arena also connects with 2 fixed stations. The adjusted stations Colorado Springs and Kansas City are connected by a chain of 3 links through Wallace and Ellsworth, and Sacramento and Salt Lake City are connected by a chain of 5 links through Verdi, Carson City, Austin, and Eureka.

D. ADJUSTMENT OF SECONDARY STATIONS AND REFERENCE TO STANDARD LONGITUDE NET.

What little adjustment is necessary in determining the longitudes of these secondary stations is made according to the method explained in full in connection with the adjustment of the longitude net. (Appendix No. 2, Report for 1897.) The weights used are derived from the probable errors of the observed differences of longitude.

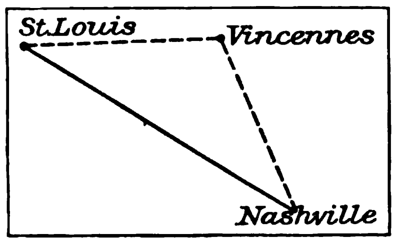
The reciprocal of the weight given in the last column of the preceding table or $\frac{1}{p} = u = \varepsilon^2 \times 10^4$, any probable error less than $\pm 0^s{\cdot}008$ being regarded as indicating a

fictitious accuracy. The nearest integer in the value of u is as great a refinement as the circumstances will warrant.

With respect to the probable error of a resulting longitude, it was found that the probable error of longitude of stations in the longitude net varies from $\pm 0^s.049$ at Washington to $\pm 0^s.055$ at San Francisco. The probable error of the secondary longitudes may safely be taken as only slightly in excess of primary stations in the same locality, say, about $\pm 0^s.050$ for stations as far west as Charleston, West Virginia, and $\pm 0^s.055$ for stations farther to the west.

ADJUSTMENT OF THE LONGITUDE TRIANGLE ST. LOUIS–NASHVILLE–VINCENNES.

No. 52.



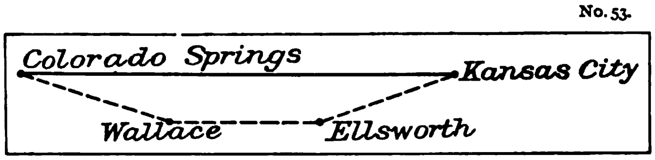
No.	Western station.	Eastern station.	Observed $\Delta\lambda$.		$u=\frac{1}{p}$.	Correction.	Adjusted $\Delta\lambda$.	
			m.	s.		s.	m.	s.
	St. Louis	Nashville					13	41.173
3	Vincennes	Nashville	2	57.891	3	+0.035	2	57.926
4	St. Louis	Vincennes	10	43.235	1	+.012	10	43.247

Observation equation $0 = -0^s.047 + (3) + (4)$
Normal equation $0 = -.047 + 4C$

$C = +0^s.011\ 8$
$(3) = +.035$
$(4) = +.012$

ADJUSTMENT OF THE LONGITUDE POLYGON COLORADO SPRINGS–WALLACE–ELLSWORTH–KANSAS CITY.

No. 53.



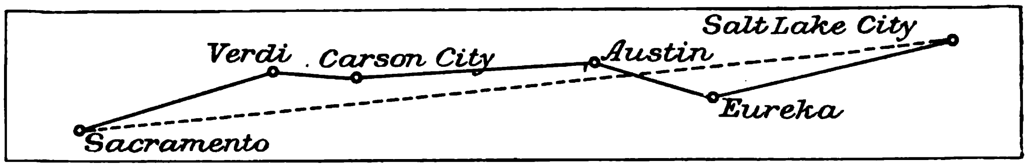
No.	Western station.	Eastern station.	Observed $\Delta\lambda$.		$u=\frac{1}{p}$.	Correction.	Adjusted $\Delta\lambda$.	
			m.	s.		s.	m.	s.
	Colorado Springs	Kansas City					40	55.306
7	Ellsworth	Kansas City	14	32.980	1	+0.040	14	33.020
8	Wallace	Ellsworth	13	27.268	1	+.039	13	27.307
9	Colorado Springs	Wallace	12	54.822	4	+.157	12	54.979

Observation equation $0 = -0^s.236 + (7) + (8) + (9)$
Normal equation $0 = -.236 + 6C$

$C = +0^s.039\ 3$
$(7) = +.040$
$(8) = +.039$
$(9) = +.157$

ADJUSTMENT OF THE LONGITUDE POLYGON SACRAMENTO–VERDI–CARSON CITY–AUSTIN–EUREKA–SALT LAKE CITY.

No. 54.



No.	Western station.	Eastern station.	Observed Δλ. m.	s.	$u=\frac{1}{p}$.	Correction. s.	Adjusted Δλ. m.	s.
	Sacramento	Salt Lake City					38	23 ·214
17	Sacramento	Verdi	6	02 ·866	1	−0 ·006	6	02 ·860
18	Verdi	Carson City	0	52 ·560	1	−0 ·006	0	52 ·554
21	Carson City	Austin	10	45 ·168	2	−0 ·011	10	45 ·157
22	Austin	Eureka	4	27 ·318	1	−0 ·006	4	27 ·312
23	Eureka	Salt Lake City	16	15 ·337	1	−0 ·006	16	15 ·331

Observation equation $0 = +0^s{\cdot}035 + (17) + (18) + (21) + (22) + (23)$

Normal equation $0 = +0{\cdot}035 + 6C$ $\qquad C = -0{\cdot}005\,8$

$(17) = -0^s{\cdot}006$

$(18) = -\ {\cdot}006$

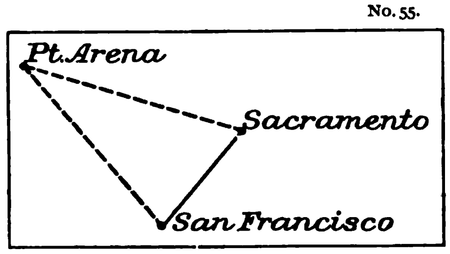
$(21) = -\ {\cdot}011$

$(22) = -\ {\cdot}006$

$(23) = -\ {\cdot}006$

ADJUSTMENT OF THE LONGITUDE TRIANGLE SACRAMENTO–SAN FRANCISCO–POINT ARENA.

No. 55.



No.	Western station.	Eastern station.	Observed Δλ. m.	s.	$u=\frac{1}{p}$.	Correction. s.	Adjusted Δλ. m.	s.
	San Francisco	Sacramento					3	44 ·474
14	Point Arena	San Francisco	5	04 ·246	1	−0 ·023	5	04 ·223
15	Point Arena	Sacramento	8	48 ·675	1	+ ·022	8	48 ·697

Observation equation $0 = -0^s{\cdot}045 - (14) + (15)$

Normal equation $0 = -\ {\cdot}045 + 2C$ $\qquad C = +0{\cdot}022\,5$

$(14) = -0^s{\cdot}023$

$(15) = +\ {\cdot}022$

E. RESULTING STANDARD LONGITUDES.

The following standard longitudes west of Greenwich are taken from the adjustment of the general longitude net:

	Time.	Arc.
	h. m. s.	° ′ ″
Cape May, Transit, New Jersey	4 59 43·045	74 55 45·68
Washington, Transit, United States Coast and Geodetic Survey Office, District of Columbia	5 08 01·709	77 00 25·64
Washington, Dome of United States Naval Observatory, old site, District of Columbia	5 08 12·153	77 03 02·30
Washington, clock room of United States Naval Observatory, new site, District of Columbia	5 08 15·784	77 03 56·76
* Detroit, Transit of 1891, Michigan	5 32 11·830	83 02 57·45
Cincinnati, Dome of Mount Lookout Observatory, Ohio	5 37 41·398	84 25 20·97
Louisville, Transit, Kentucky	5 43 03·636	85 45 54·54
* Nashville, Transit, Tennessee	5 47 08·083	86 47 01·24
Saint Louis, Transit of 1882, Missouri	6 00 49·256	90 12 18·84
Kansas City, Transit, Missouri	6 18 21·404	94 35 21·06
Colorado Springs, Transit of 1885–86, Colorado	6 59 16·710	104 49 10·65
Salt Lake City, Transit, Utah	7 27 35·173	111 53 47·60
Ogden, East Transit in west room of Engineer's Observatory, Utah	7 27 59·706	111 59 55·59
Sacramento, Transit, California	8 05 58·387	121 29 35·80
San Francisco, Transit, Lafayette Park, California	8 09 42·861	122 25 42·92

By combination with the differences of longitude on preceding pages, the following additional longitudes of stations along the arc are obtained:

	Time.	Arc.
	h. m. s.	° ′ ″
Dover, Transit, Delaware	5 02 05·230	75 31 18·45
Strasburg, Transit, Virginia	5 13 26·380	78 21 35·70
Charlottesville, Transit, Virginia	5 14 05·340	78 31 20·10
Charleston, Transit, West Virginia	5 26 32·130	81 38 01·95
Vincennes, Transit, Indiana	5 50 06·009	87 31 30·14
Parkersburg, Triangulation Station, Illinois	5 52 07·220	88 01 48·30
Ellsworth, Transit, Kansas	6 32 54·424	98 13 36·36
Wallace, Transit, Kansas	6 46 21·731	101 35 25·96
Gunnison, Transit, Colorado	7 07 42·045	106 55 30·68
Grand Junction, Transit, Colorado	7 14 15·601	108 33 54·02
Green River Transit, Utah	7 20 39·539	110 09 53·08
Oasis, Transit, Utah	7 30 31·694	112 37 55·41
Eureka Transit, Nevada	7 43 50·504	115 57 37·56
Austin, Transit, Nevada	7 48 17·816	117 04 27·24
Virginia City, Transit, Nevada	7 58 34·805	119 38 42·08
Carson City, Transit of 1889, Nevada	7 59 02·973	119 45 44·60
Genoa, Transit, Nevada	7 59 21·489	119 50 22·34
Lake Tahoe, Southeast, Transit, California	7 59 47·060	119 56 45·90
Verdi, Transit, Nevada	7 59 55·527	119 58 52·90
Marysville, Transit, California	8 06 21·186	121 35 17·79
Mount Hamilton, Lick Observatory Transit house, California	8 06 34·895	121 38 43·42
San Francisco, Transit, Washington Square, California	8 09 38·441	122 24 36·62
San Francisco, Transit, Presidio, California	8 09 48·813	122 27 12·20
Ukiah, Transit, California	8 12 50·234	123 12 33·51
Point Arena, Transit, California	8 14 47·084	123 41 46·26

* Not on the transcontinental triangulation.

PART VII.

THE GEOGRAPHIC POSITIONS AND COMPARISON OF THE ASTRONOMIC AND GEODETIC RESULTS.

PRELIMINARY COMBINATION OF AMERICAN ARCS FOR DETERMINING THE EARTH'S FIGURE.

CONTENTS OF PART VII.

VII. THE GEOGRAPHIC POSITIONS AND COMPARISON OF THE ASTRONOMIC AND GEODETIC RESULTS. PRELIMINARY COMBINATION OF AMERICAN ARCS FOR DETERMINING THE EARTH'S FIGURE

A. GEOGRAPHICAL COORDINATES OF THE STATIONS COMPOSING THE TRANSCONTINENTAL TRIANGULATION AND THE MEASURE OF THE ARC IN LATITUDE 39°.

The angles and length of sides of the triangulation extending from the Atlantic to the Pacific Ocean along the parallel of 39° were given in Part III. These data were derived from the adjustment of the angular measures in order to satisfy the internal or geometric conditions of the triangulation as well as to produce perfect accord between the measured lengths of the several interspersed base lines. The next step to be taken was a preliminary computation of the geodetic coordinates of the astronomic stations, so that the astronomic and geodetic results could be compared and standard *geodetic* data (latitude, longitude, and azimuth) determined. This first or provisional systematic position computation over the adjusted triangulation was started in the East, before the adjustment of the western part had been completed. It was based upon the Clarke Spheroid of 1866, and was made by means of the formulæ customarily employed on the Survey. Their derivation together with the tables for facilitating their use will be found in Appendix No. 9, Coast and Geodetic Survey Report for 1894, pp. 279–348.* These formulæ are:

$$\left\{\begin{array}{l} -\Delta\varphi = s\cos\alpha\,.\,B + s^2\sin^2\alpha\,.\,C + (\delta\varphi)^2\,.\,D - hs^2\sin^2\alpha\,.\,E \\ \quad\Delta\lambda = s\sin\alpha\sec\varphi'\,.\,A \\ -\Delta\alpha = \Delta\lambda\sin\tfrac{1}{2}(\varphi+\varphi')\sec\tfrac{1}{2}(\Delta\varphi) + (\Delta\lambda)^3\,.\,F \end{array}\right.$$

$$\text{where}\left\{\begin{array}{ll} \varphi' = \varphi + \Delta\varphi & \text{and } -\delta\varphi = s\cos\alpha\,.\,B + s^2\sin^2\alpha\,.\,C - hs^2\sin^2\alpha\,.\,E \\ \lambda' = \lambda + \Delta\lambda & \text{also } h = s\cos\alpha\,.\,B \\ \alpha' = \alpha + \Delta\alpha + 180^\circ & \end{array}\right.$$

These formulæ answer for triangles of ordinary size, but for sides much exceeding 1° (or 111 kilometres) an additional term in the development of the expression for $-\Delta\varphi$ may become sensible, viz.—

$$-\tfrac{1}{2}\,s^2C_1E + \tfrac{3}{2}\,s^2\cos^2\alpha\,.\,C_1E + \tfrac{1}{2}\,s^2\cos^2\alpha\sec^2\varphi\,.\,A^2\,.\,C_1\,\text{arc}^2\,1'', \text{ where } C_1 = s^2\sin^2\alpha\,.\,C$$

*In *last* line of footnote, p. 289: for [8·509 0] read [8·230 8].

as developed by Mr. M. H. Doolittle. This term only demanded attention for the longer sides of the triangulation across the western section of the arc.*

Respecting the nature of the curve connecting two triangulation stations, we may regard it as a line of alignment† (Clarke) at every point of which the azimuths of the terminal stations differ 180°. It has the advantage over a geodetic line of having the direction of its first element *ds* at each station coincident with the direction of the theodolite when pointed to the opposite station, whereas in the case of the geodetic line there is an abrupt angular deviation which calls for special computation, since the line is not directly observable. Both curves are tortuous. With respect to length between two fixed positions, there is no practically appreciable difference whether we conceive the connecting line to be an elliptic arc, a line of alignment, or a geodetic line. The line of alignment, like the geodetic line, ordinarily lies between the two elliptic arcs, but the latter line may deviate widely from or be wholly outside them under certain conditions, depending upon near equality in the latitudes of the terminals.

The geodetic positions of the astronomic stations as derived from the provisional position computation and checked by a double computation are given in the following table of comparisons of astronomic and geodetic values. The astronomic latitudes are taken from Part IV, azimuths from Part V, and longitudes from Part VI.

B. COMPARISON OF ASTRONOMIC AND PROVISIONAL GEODETIC MEASURES.

Provisional position of station "Hays." $\begin{cases} \varphi = 38° \; 54' \; 50''.82 \\ \lambda = 99 \; 16 \; 16.36 \\ \alpha = 359 \; 44 \; 19.00 \text{ to Lacrosse.} \end{cases}$

I. LATITUDES.

Comparison of astronomic and provisional geodetic latitudes.

No.	Name of astronomic station.	Observed astronomic latitude.	Seconds of geodetic latitude.	Δφ (A–G)
		° ′ ″	″	″
1	Cape May (astronomic station)	38 55 44·63	47·12	−2·49
2	Cape Henlopen	38 46 40·07	40·57	−0·50
3	Dover	39 09 13·47	19·18	−5·71
4	Principio	39 35 32·75	35·14	−2·39
5	Poole Island	39 17 17·52	14·11	+3·41
6	Calvert	38 21 31·71	32·76	−1·05
7	Taylor	38 59 46·07	46·94	−0·87
8	Marriott	38 52 25·05	26·28	−1·23
9	Webb	39 05 25·35	24·76	+0·59
10	Hill	38 53 52·36	52·83	−0·47
11	Soper	39 05 10·61	10·40	+0·21
12	Seaton	38 53 25·12	27·42	−2·30
13	Coast and Geodetic Survey Office, observatory in yard	38 53 07·35	10·60	−3·25
14	United States Naval Observatory, old (dome)	38 53 38·78	40·72	−1·94
15	United States Naval Observatory, new (clock room)	38 55 13·74	15·49	−1·75
16	Causten	38 55 32·02	33·41	−1·39
17	Georgetown College Observatory (dome)	38 54 25·79	28·40	−2·61
18	Rockville	39 05 10·42	09·68	+0·74
19	Sugar Loaf	39 15 49·54	44·25	+5·29
20	Maryland Heights	39 20 32·19	26·90	+5·29
21	Bull Run	38 52 56·72	52·68	+4·04
22	Strasburg	38 59 31·56	28·42	+3·14
23	Clark Mountain	38 18 39·60	39·82	−0·22
24	Charlottesville, McCormick Observatory (transit)	38 01 61·09	56·52	+4·57
25	Long Mountain	37 17 28·84	26·10	+2·74
26	Elliott Knob	38 09 57·08	58·11	−1·03
27	Keeney	37 46 23·07	24·12	−1·05

* For the line Ibepah to Ogden Peak, 230 kilometres in length, this term amounts to 0″·038.

† Bremiker's "Feldlinie."

Comparison of astronomic and provisional geodetic latitudes—Completed.

No.	Name of astronomic station.	Observed astronomic latitude.	Seconds of geodetic latitude.	Δφ (A–G)
		° ′ ″	″	″
28	Charleston	38 21 06·95	00·83	+6·12
29	Piney	38 26 41·40	38·58	+2·82
30	Gould	38 38 29·78	28·15	+1·63
31	Minerva	38 42 30·89	29·75	+1·14
32	Mount Lookout Observatory (dome)	39 08 19·65	19·52	+0·13
33	Reizin	39 02 53·76	52·46	+1·30
34	Weed Patch	39 09 60·68	59·28	+1·40
35	Vincennes	38 40 36·80	34·37	+2·43
36	Parkersburg, Triangulation Station	38 34 53·05	50·20	+2·85
37	Olney West Base, Triangulation Station	38 51 41·28	37·25	+4·03
38	Newton	38 55 31·10	27·27	+3·83
39	Bording	38 36 50·93	44·02	+6·91
40	St. Louis University (referred to Second Presbyterian Church)	38 37 60·59	54·92	+5·67
41	Jefferson City	38 33 43·95	39·95	+4·00
42	Hunter	38 25 48·00	44·01	+3·99
43	Kansas City	39 05 51·12	49·25	+1·87
44	Adams	39 02 41·80	39·92	+1·83
45	Salina West Base	38 51 03·52	06·60	−3·08
46	Ellsworth	38 43 47·49	47·70	−0·21
47	Russell Southeast	38 51 22·73	21·26	+1·47
48	Wallace	38 54 44·25	43·39	+0·86
49	Adobe	38 40 37·42	39·95	−2·53
50	El Paso East Base	38 57 16·50	21·32	−4·82
51	Colorado Springs	38 49 59·98	62·38	−2·40
52	Pikes Peak	38 50 27·28	25·45	+1·83
53	Mount Ouray	38 25 18·00	22·03	−4·03
54	Treasury Mountain	39 00 47·25	50·31	−3·06
55	Gunnison, Colorado	38 32 44·39	46·28	−1·89
56	Uncompahgre	38 04 15·74	17·34	−1·60
57	Grand Junction	39 03 59·04	54·47	+4·57
58	Tavaputs	39 32 17·12	23·83	−6·71
59	Mount Waas	38 32 29·00	19·85	+9·15
60	Green River	38 59 23·63	29·57	−5·94
61	Patmos Head	39 29 56·86	69·67	−12·81
62	Mount Ellen	38 07 24·17	15·96	+8·21
63	Wasatch	39 06 53·83	56·76	−2·93
64	Mount Nebo	39 48 32·31	37·86	−5·55
65	Gunnison, Utah	39 09 25·46	30·38	−4·92
66	Ogden Peak	41 11 59·22	60·12	−0·90
67	Salt Lake City	40 46 03·36	11·72	−8·36
68	Ogden Observatory, longitude pier	41 13 08·33	11·89	−3·56
69	Waddoup	40 54 21·73	23·35	−1·62
70	Antelope	40 57 40·16	43·40	−3·24

No.	Name of astronomic station.	Observed astronomic latitude.	Seconds of geodetic latitude.	Δφ (A–G)
		° ′ ″	″	″
71	Promontory	41 17 47·77	53·04	−5·27
72	Deseret	40 27 31·25	34·35	−3·10
73	Beaver	38 16 22·90	24·99	−2·09
74	Oasis	39 17 35·29	37·33	−2·04
75	Ibepah	39 49 38·97	42·09	−3·12
76	Pilot Peak	41 01 07·83	16·61	8·78
77	Pioche	37 59 06·80	10·60	−3·80
78	Pioche United States Engineer Station	37 55 25·80	37·96	−12·16
79	Diamond Peak	39 35 03·65	06·67	−3·02
80	Mount Callahan	39 42 31·92	34·92	−3·00
81	Toiyabe Dome	38 49 53·91	59·02	−5·11
82	Carson Sink	39 34 57·67	60·24	−2·57
83	Carson City, Observatory (Zenith telescope)	39 09 47·25	51·84	−4·59
84	Verdi	39 31 04·29	05·72	−1·43
85	Lake Tahoe Southeast	38 57 19·37	16·32	+3·05
86	Mount Conness	37 57 55·98	58·83	−2·85
87	Round Top	38 39 46·27	49·90	−3·63
88	Mount Lola	39 25 57·37	59·90	−2·53
89	Mocho	37 28 36·71	39·35	−2·64
90	Marysville	39 08 12·27	19·30	−7·03
91	Mount Hamilton, Lick Observatory, United States Coast and Geodetic Survey station	37 20 28·85	34·46	−5·61
92	Yolo Southeast Base	38 31 34·55	42·29	−7·74
93	Yolo Northwest Base	38 40 37·25	44·61	−7·36
94	Mount Diablo	37 52 49·60	55·12	−5·52
95	Vaca	38 22 23·27	33·11	9·84
96	Monticello	38 39 46·26	50·63	−4·37
97	San Francisco, Washington Square	37 47 56·90	64·40	−7·50
98	San Francisco, Lafayette Park	37 47 28·31	31·60	−3·29
99	San Francisco, Presidio, old	37 47 35·96	38·84	2·88
100	San Francisco, Presidio, new	37 47 48·35	51·06	−2·71
101	Mount Tamalpais	37 55 19·18	27·24	8·06
102	Mount Helena	38 40 01·05	09·82	8·77
103	Ross Mountain	38 30 09·96	20·29	−10·33
104	Sulphur Peak	38 45 44·42	53·97	9·55
105	Ukiah	39 08 54·59	58·55	3·96
106	Point Reyes	37 59 33·62	44·00	10·38
107	Bodega	38 18 20·11	29·55	9·44
108	Mendocino City	39 18 05·50	13·19	7·69
109	Point Arena	38 55 10·16	18·66	8·50

2. AZIMUTHS.

Comparison of astronomic and provisional geodetic azimuths.

No.	Stations occupied.	Station referred to.	Observed astronomic azimuth West of South.	Seconds of geodetic azimuth.	Δa (A–G)
			° ′ ″	″	″
1	Cape Henlopen Light	Brandywine Shoal Lighthouse	173 45 17·64	15·56	+2·08
2	Principio	Turkey Point	1 34 43·50	34·85	+8·65
3	Calvert	Meekin Neck	252 06 09·18	01·08	+8·10
4	Marriott	Hill	96 37 43·40	35·29	+8·11
5	Webb	Soper	88 59 49·38	42·96	+6·42
6	Hill	Webb	219 46 58·11	51·38	+6·73
7	Soper	Webb	268 49 23·60	18·40	+5·20
8	Seaton	Hill	265 32 53·61	43·80	+9·81
9	Causten	Soper	210 54 41·65	37·83	+3·82
10	Sugar Loaf	Bull Run	32 29 16·97	22·53	−5·56
11	Maryland Heights	Bull Run	358 43 07·18	10·78	−3·60
12	Bull Run	Peach Grove	263 53 28·49	30·84	−2·35
13	Clark Mountain	Bull Run	202 19 27·98	29·05	−1·07
14	Long Mount	Spear	223 28 41·64	46·89	−5·25
15	Elliott Knob	Humpback	303 25 24·46	22·49	+1 97
16	Keeney	Bald Knob	257 04 35·89	33·96	+1·93
17	Piney	Gebhardt	119 04 31·84	32·88	−1·04
18	Gould	Howland	84 49 13·61	11·44	+2·17
19	Minerva	Ash Ridge	210 54 42·38	47·75	−5·37
20	Reizin	Tanner	276 56 46·02	49·12	−3·10
21	Weed Patch	Fountain	7 33 21·28	22·14	−0·86
22	Osborn	Calvary	192 16 17·59	18·47	−0·88
23	Parkersburg	Denver	143 16 15·55	17·34	−1·79
24	Newton	Claremont	321 29 05·30	06·33	−1·03
25	Bording	Geoffrey	53 25 07·53	05·89	+1·64
26	Kleinschmidt	Insane Asylum	200 09 31·81	30·83	+0·98
27	Berger	Winter	39 12 05·64	03·15	+2·49
28	Jefferson City	Cedar	199 55 37·47	36·01	+1·46
29	Hunter	Christian	221 48 20·49	23·24	−2·75
30	Adams	Clark	11 46 11·94	12·42	−0·48
31	Salina West Base	Salina East Base	248 36 18·32	24·24	−5·92
32	Russell Southeast	Russell Northwest	140 42 59·79	67·9	−8·11
33	Overland	Eureka	284 10 32·62	33·57	−0·95
34	El Paso East Base	El Paso West Base	102 48 04·62	03·19	+1·43
35	Pikes Peak	Mount Ouray	66 05 16·70	10·99	+5·71
36	Mount Ouray	Uncompahgre	70 35 51·27	54·20	− 2·93
37	Gunnison, Colorado	Uncompahgre	41 55 00·39	11·65	−11·26
38	Treasury Mountain	Mount Waas	74 45 04·71	18·21	−13·50
39	Uncompahgre	Treasury Mountain	196 42 55·84	64·02	− 8·18
40	Grand Junction	Chiquita	23 57 23·98	31·83	− 7·85

Comparison of astronomic and provisional geodetic azimuth—Completed.

No.	Stations occupied.	Station referred to.	Observed astronomic azimuth West of South.	Seconds of geodetic azimuth.	$\Delta\alpha$ (A–G)
			° ′ ″	″	
41	Tavaputs	Patmos Head	88 17 40·85	46·84	− 5·99
42	Mount Waas	Mount Ellen	72 00 16·62	30·55	−13·93
43	Patmos Head	Wasatch	66 41 18·70	29·65	−10·95
44	Mount Ellen	Patmos Head	195 35 57·89	64·33	− 6·44
45	Wasatch	Mount Nebo	160 54 02·73	12·14	− 9·41
46	Mount Nebo	Tushar	20 05 23·06	40·96	−17·90
47	Salt Lake City	City Creek	192 02 50·50	68·52	−18·02
48	Waddoup	Ogden Peak	180 42 32·55	56·43	−23·88
49	Ogden Observatory	Ogden Peak	283 08 44·70	61·31	−16·61
50	Ogden Peak	Mount Nebo	356 19 30·37	44·10	−13·73
51	Antelope	Deseret	31 59 04·14	13·43	− 9·29
52	Promontory	Ogden Peak	283 24 02·64	02·90	− 0·26
53	Deseret	Mount Nebo	314 14 01·38	14·55	−13·17
54	Ibepah	Diamond Peak	81 11 28·49	36·08	− 7·59
55	Pioche	Tushar	250 58 50·29	58·38	− 8·09
56	Pilot Peak	Mount Nebo	303 40 14·15	19·00	− 4·85
57	Diamond Peak	Mount Callahan	98 27 13·82	19·46	− 5·64
58	Mount Callahan	Carson Sink	83 09 34·84	41·78	− 6·94
59	Toiyabe Dome	Mount Grant	77 20 49·29	58·29	− 9·00
60	Carson Sink	Mount Callahan	262 20 25·50	31·08	− 5·58
61	Mount Conness	Round Top	142 39 19·46	29·72	−10·26
62	Lake Tahoe Southeast	Folsom Peak	177 56 19·13	29·2	−10·1
63	Round Top	Mount Helena	90 58 53·89	59·58	− 5·69
64	Mount Lola	Mount Helena	67 22 02·36	05·83	− 3·47
65	Mocho	Mount Diablo	144 57 35·71	42·38	− 6·67
66	Yolo Base Southeast	Yolo Base Northwest	163 07 13·11	21·37	− 8·26
67	Yolo Base Northwest	Yolo Base Southeast	343 05 02·07	10·32	− 8·25
68	Mount Diablo	Mount Helena	144 28 16·03	21·28	− 5·25
69	Vaca	Yolo Base Southeast	235 38 36·55	39·70	− 3·15
70	Monticello	Mount Helena	91 04 25·30	30·04	− 4·74
71	Mount Tamalpais	Mount Diablo	274 15 15·04	21·84	− 6·80
72	Mount Helena	Mount Diablo	324 01 24·96	37·22	−12·26
73	Paxton	Mount Sanhedrin	203 47 05·77	17·07	−11·30

3. LONGITUDES.

Comparison of astronomic and provisional geodetic longitudes.

No.	Name of astronomic station.	Observed astronomic longitude.	Seconds of geodetic longitude.	$\Delta\lambda$ (A–G)
		° ′ ″	″	″
1	Cape May, astronomic station	74 55 45·68	47·44	− 1·76
2	Dover	75 31 18·45	23·93	− 5·48
3	Washington, Coast and Geodetic Survey Office (observatory in yard)	77 00 25·64	32·13	− 6·50
4	Washington, old Naval Observatory, dome	77 03 02·30	06·11	− 3·81
5	Washington, new Naval Observatory, clock room	77 03 56·76	62·23	− 5·47
6	Strasburg	78 21 35·70	38·97	− 3·27
7	Charlottesville, McCormick Observatory	78 31 20·10	20·60	− 0·50
8	Charleston, West Virginia	81 37 61·95	59·11	+ 2·84
9	Cincinnati, Mount Lookout Observatory transit	84 25 20·97	21·21	− 0·24
10	Vincennes	87 31 30·14	34·84	− 4·70
11	Parkersburg, transit	88 01 48·30	48·79	− 0·49
12	St. Louis, transit of 1881	90 12 18·84	17·18	+ 1·66
13	Kansas City	94 35 21·06	21·82	− 0·76
14	Ellsworth	98 13 36·36	44·59	− 8·23
15	Wallace	101 35 25·96	31·06	− 5·10
16	Colorado Springs	104 49 10·65	34·22	−23·57
17	Gunnison, Colorado	106 55 30·68	26·23	+ 4·45
18	Grand Junction	108 33 54·02	52·87	+ 1·15
19	Green River	110 09 53·08	55·12	− 2·04
20	Salt Lake City	111 53 47·60	26·63	+20·97
21	Ogden Observatory transit, longitude pier	111 59 55·59	37·28	+18·31
22	Oasis	112 37 55·41	43·70	+11·71
23	Eureka	115 57 37·56	30·01	+ 7·55
24	Austin	117 04 27·24	11·57	+15·67
25	Virginia City	119 38 42·08	49·32	− 7·24
26	Carson City, transit Friend Observatory	119 45 44·60	48·39	− 3·79
27	Genoa	119 50 22·34	45·72	−23·38
28	Lake Tahoe Southeast	119 56 45·90	40·40	+ 5·50
29	Verdi	119 58 52·90	57·49	− 4·59
30	Sacramento	121 29 35·80	29·85	+ 5·95
31	Marysville	121 35 17·79	09·70	+ 8·09
32	Mount Hamilton, Lick Observatory, transit house	121 38 43·42	30·23	+13·19
33	San Francisco, Washington Square	122 24 36·62	30·93	+ 5·69
34	San Francisco, Lafayette Park	122 25 42·92	36·64	+ 6·28
35	San Francisco, Presidio (new)	122 27 12·20	04·65	+ 7·55
36	Ukiah	123 12 33·51	27·44	+ 6·07
37	Point Arena	123 41 46·26	23·79	+22·47

4. PRELIMINARY EXAMINATION OF THE RESULTS OF THE COMPARISON OF THE ASTRONOMIC AND THE PROVISIONALLY ADOPTED GEODETIC POSITIONS AS PRESENTED IN THE PRECEDING TABLES.

These preliminary values of the respective differences $(A-G)$ in latitude, longitude, and azimuth suffice to indicate in outline the general character of the results we may derive from the measurement of the arc. They may therefore be advantageously scrutinized in a general way before proceeding to the determination of the final corrections to our geodetic coordinates.

In the first place, we notice that the greater number of the differences range within a few seconds and present changes of sign, thus showing that the provisional values of φ λ α for the central station can not be much in error; on the other hand, large deviations appear at certain stations, but these are readily and directly traced to local conditions or surface configurations and are not in any way referable to a defective spheroid of reference.

The prevailing negative sign in the values of $\triangle\varphi$ indicates the need of a slight diminution of the provisional value of φ, in order to make $[A-G] = o$, a condition which appears already nearly satisfied for the eastern and central part of the arc, whereas the western or mountainous region calls for the indicated correction in a more

decided way. In this we may possibly discern a change in the curvature of the western section of the arc. Turning now our attention to the tabular values of $\triangle\lambda$ and $\triangle\alpha$, we find in both cases a certain sign to prevail in the eastern section of the arc with the *opposite* sign in the western section, and further, as it should be by virtue of the relation $\triangle\alpha = -\triangle\lambda \sin\varphi$, to a + or − value for $\triangle\lambda$ there corresponds in general or in the same section a − or + value for $\triangle\alpha$. In the east the values of $\triangle\alpha$ are preeminently positive, in the west they are preeminently negative, while in magnitude of deflection there is but a slignt difference, and probably only a small correction to the provisional value may be needed. It is the longitude differences $\triangle\lambda$, however, which for the arc are of greatest importance. They open in the eastern section with negative sign, turning to positive in the western section. In other words, the astronomic amplitude of the whole arc (48° 46′ 00″·58) is greater than the provisional geodetic one (48° 45′ 36″·35). There are three prominent causes which undoubtedly go to make up the greater part of this difference. In the first place, our reference spheroid does not exactly fit the curvature of the arc; secondly, the continental attraction may have a sensible effect, and thirdly, there is the influence of the local deflections. If the reference spheroid be too large—that is, if the triangulation is placed and developed upon a surface less curved than is actually the case—a difference in the sense of astronomic amplitude greater than geodetic amplitude will follow; hence a spheroid of smaller dimension (in the parallel of 39°) seems to be called for. In the second place, the attraction of the continental masses near the terminals of the arc tends to a deflection of the plumb line to the westward (or disturbed zenith to the eastward of the normal) on the Atlantic coast and to the eastward on the Pacific coast. This is equivalent to an enlargement of the astronomic amplitude. An effect of this character might, to some extent, be counteracted by the sea bottom being supposed as composed of heavier material than the continental mass, thus partly overcoming the influence of the less dense overlying sea water. It is well known that off the New Jersey coast the water shoals very gradually and that the actual or more prominent, but submerged border of the continent, lies far to the east of the present coast line. At a distance from shore of 85 nautical miles (minutes of arc) on the parallel of 39° we reach the contour line of 50 fathoms (91 metres), but 30 nautical miles farther to the east we plunge into a depth of 1 000 fathoms (1 829 metres). On the Atlantic coast then we may expect but a feeble disturbing influence on the vertical, as compared with the conditions which prevail on the Pacific coast, where the descent of the bottom from the coast line into deep water is immediate, giving a depth of 100 fathoms 10 nautical miles out and a depth of 1 832 fathoms at 40 nautical miles on the parallel of 39°. Besides, we have there on the land side the attracting influence of the coast range of mountains, which rises at that point to a height of more than 2 000 feet (610 metres). By far the principal part of the deflection of the vertical in the plane of the prime vertical supposed due to the cause under consideration must therefore be attributed to the western terminus of the arc.

The great influence which the local deflections exert upon the measures of the arc is well shown by the following table of comparisons of astronomic and geodetic amplitudes of the whole and part of the arc:

Whole or part of arc	Amplitude. Astronomic.	Amplitude. Geodetic.	Difference.
	° ′ ″	° ′ ″	″
Whole arc, Cape May to Point Arena, No. (37—1)	48 46 00·58	48 45 36·35	+24·23
Stations next to terminals, Dover to Ukiah, No. (36—2)	47 41 15·06	47 41 03·51	+11·55
District of Columbia group to San Francisco group, Nos. (33, 34, 35—3, 4, 5)	45 23 22·35	45 23 10·58	+11·77
Strasburg and Charlottesville group and California group, Nos. (30, 31, 32—6, 7)	43 08 04·44	43 07 53·48	+10·96

(C) DETERMINATION OF STANDARD (GEODETIC) VALUES FOR LATITUDE AND LONGITUDE OF INITIAL STATION HAYS, AND AZIMUTH OF LINE HAYS TO LA CROSSE.

For the initial station from which to begin the final computation of geographic positions "Hays" has been selected, as being very nearly in the middle of the arc. The provisional computation gave the following results for that station: $\varphi = 38° \; 54' \; 50''\cdot 82$, $\lambda = 99° \; 16' \; 16''\cdot 36$, and $\alpha = 359° \; 44' \; 19''\cdot 00$ to station La Crosse. It remains to determine such corrections to these values as will yield the geodetic data best suited for the whole triangulation. Were it not for the presence of local deflections in the vertical of the stations, this would be a simple matter, nothing more than taking the means of the quantities in the column headed $(A-G)$ in the preceding tables for each of the three elements, φ, λ, and α, so that finally the condition $[A-G] = o$ would be satisfied for each. In the absence of accurate knowledge concerning the amount and direction of the local deflection, as well as of their local distribution, we must modify this simple method, in order to avoid as much as possible their disturbing effect.

These deflections of the vertical may be regarded either as quite local, or as extending over large regions. The former may be recognized as mainly depending in direction and sign upon surrounding local surface irregularities, or upon obvious deviations from average surface density; the latter are characterized by large and nearly constant deflections, covering vast areas, which may be due to the presence of irregular density of the matter forming the earth's crust, or to the proximity of mountain ranges, continental masses, plateaus, or the sea.

While the deflections elude exact computation from want of the required data, their influence in determining standard geodetic data can be lessened by bringing a large number of astronomic determinations to bear upon the problem. It is desirable that the astronomic stations should be uniformly distributed over the whole arc. Where the stations are unduly crowded in any particular locality, it would be better in determining the standard data to substitute a mean value of $(A-G)$ for this region, in place of the individual values. For instance, it would be better when determining φ_o to introduce a single representative station, in place of the several latitude stations crowded into the narrow limits of the District of Columbia. It is also plain that stations of large local deflection should be excluded. Thus the local deflection in longitude of nearly 25″ of arc at Colorado Springs, which is mainly due to the attraction of Pikes Peak and the mountain masses lying back of it, would necessarily exclude that station when forming λ_o.

The average local deflection of the vertical in the plane of the meridian from 60 cases of latitude comparisons of stations, located on the oblique arc between Calais, Maine, and Atlanta, Georgia,* was found to be $2''.4$, irrespective of sign, and about the same amount follows from the 51 latitude comparisons of that part of the present arc between Cape May and Colorado Springs. For the mountainous part of this arc, however, the average deviation from the vertical of a standard reference spheroid would have to be considerably increased. There is no special reason to expect the longitudinal deviations to be any greater or less than the latitudinal ones. The effect upon the general mean, when omitting all values of $(A-G)$ greater than 8 seconds, is shown farther on in the case of the latitudes.

There is consequently an arbitrary feature in the process, yet practically this may be confined to narrow limits without seriously affecting the derived values.

The values of φ_0, λ_0, and α_0 having been finally and satisfactorily determined, as shown by the remaining deflections, we may also expect that any subsisting Laplace equation of the form—

$$(\alpha_{\text{Ast.}} - \alpha_{\text{Geod.}}) + (\lambda_{\text{Ast.}} - \lambda_{\text{Geod.}}) \sin \varphi = 0$$

will be found nearly satisfied. The importance of these equations has perhaps been much overrated; they nevertheless demand attention. In laying out field work, however, the selection of a longitude station depends mainly on the availability of telegraphic wire connection, while that of an azimuth station demands free visibility of surrounding principal trigonometric stations—conditions generally incompatible with one another.

In accordance with the principles laid down above, we derive the following values as corrections to the preliminary latitude:

	Using all tabular values $(A-G)$.	After rejecting all values greater than 8″.
	$''$	$''$
(*a*) Indiscriminate mean	$-\frac{211.54}{109} = -1.94$	$-\frac{111.92}{95} = -1.18$
(*b*) After formation into groups†	$-\frac{34.64}{57} = -0.61$	$-\frac{34.49}{56} = -0.64$
(*c*) Mean of the 34 groups of the central and eastern sections	$+\frac{36.79}{34} = +1.08$	$+\frac{36.79}{34} = +1.08$
(*d*) Mean of groups of western section	$-\frac{71.49}{23} = -3.11$	$-\frac{72.74}{22} = -3.31$

Evidently the *distribution* of the astronomic stations is here of more importance than the rejection of large deflections, while at the same time an antagonism between the sections of the arc, i. e., $(c) - (d) = +4''.19$ and $+4''.39$ is brought out instead of zero. For the correction to the preliminary latitudes for the whole arc the value $-0''.64$ from the above table is adopted; hence $\varphi_0 = \varphi - 0''.64 = 38^\circ\ 54'\ 50''.18$ for the geodetic latitude of Hays station. The uncertainty of this value is estimated to be less than half a second.

*Appendix No. 8, Coast and Geodetic Survey Report for 1879. Table on page 115.

†Groups: (1, 2); (7, 8, 9); (10, 11, 12, 13, 14, 15, 16, 17); (20, 21); (22, 24); (25, 26); (28, 29); (36, 37, 38); (51, 52); (54, 55); (58, 59); (60, 61); (64, 65, 66, 67, 68, 69); (70, 71); (72, 73, 74); (75, 76, 77, 78); (83, 84, 85, 87, 88); (89, 90, 91, 92, 93, 94, 95, 96); (97, 98, 99, 100, 101, 102); (103, 104, 105, 106, 107); (108, 109).

To find the linear change of length of a given arc of parallel when moved a number of seconds to the north or south of its position on the spheroid, we have: Length in metres of 1° in latitude φ—

$$P^{\circ} = 111\ 415{\cdot}12 \cos \varphi - 94{\cdot}54 \cos 3\varphi + 0{\cdot}12 \cos 5\varphi - \ldots\ldots$$

$$\text{and } \frac{dP}{d\varphi} = -111\ 415{\cdot}12 \sin \varphi + 283{\cdot}62 \sin 3\varphi - 0{\cdot}60 \sin 5\varphi$$

Hence for $\varphi = 39°$ and $d\varphi = 0''{\cdot}5$ and length of arc $48\frac{3}{4}°$, the change is 8·25 metres, which in comparison with the probable error in length of the geodetic connection is a small quantity.*

For the correction to the preliminary longitude we have the following data:

	Using all tabular values (A–G).	After rejection of the nine largest values.
	$''$	$''$
(a) Indiscriminate mean	$+\frac{43{\cdot}39}{37} = +1{\cdot}17$	$+\frac{7{\cdot}04}{28} = +0{\cdot}25$
(b) Mean after forming groups†	$+\frac{31{\cdot}80}{25} = +1{\cdot}27$	$+\frac{7{\cdot}01}{19} = +0{\cdot}37$

Adopting the last value, we have $\lambda_0 = \lambda + 0''{\cdot}37 = 99°\ 16'\ 16''{\cdot}73$ for the final geodetic longitude of Hays station. The uncertainty of this value may be estimated as less than 1″.

Respecting any change in azimuth, the values of (A–G) at the eastern and near the western parts of the arc (first and last nine stations) appear fairly well balanced, while the stations of the western or mountainous section exhibited a predominating negative sign. In order to remove this feature, the geodetic azimuths would need a diminution, which, however, is opposed to the apparent demand for the eastern part of the arc. A small change of azimuth has but a small effect upon the latitudes and hardly any upon the longitudes. Upon the whole it has been concluded to make no change in the azimuth; hence $\alpha_0 = \alpha = 359°\ 44'\ 19''{\cdot}00$ for the line Hays to LaCrosse.

With the standard values of φ_0, λ_0, and α_0 for Hays station the geodetic latitudes and longitudes of all the stations of the arc were recomputed and the definitive results of comparison of the astronomic and geodetic determinations are tabulated below.

In order to render this comparison more complete, there are also given the positions and resulting values of (A–G) when the Besselian spheroid is substituted for that of Clarke. It must be noted, however, that only a close approximation of these values could here be given, since, in strictness, the subject would demand a readjustment of the entire triangulation with the introduction of the spherical excess appertaining to the Besselian spheroid. The difference in the excess ‡ is small, even for the largest triangle "Tushar, Wheeler, Nebo," for which $\varepsilon = 73''{\cdot}758\,4$. The difference in ε is but $0''{\cdot}017\,1$, or $\frac{1}{4314}$ of itself, and for the greater part of the arc the hundredths of a second for any angle would not be modified by the change of spheroids. There is nevertheless a small accumulated effect in the positions which may tend to introduce a twist, yet this is fully

* For Bessel's spheroid we have $P^{\circ} = 111\ 399^{m}{\cdot}675 \cos\varphi - 93{\cdot}212 \cos 3\varphi + 0{\cdot}116 \cos 5\varphi - \ldots\ldots$

† Groups: (3, 4, 5); (6, 7); (20, 21); (25, 26, 27, 28, 29); (30, 31, 32), and (33, 34, 35).

‡ The effect on the spherical excess of a triangle by a change of dimensions in the spheroid is given by the expression $\frac{d\varepsilon}{\varepsilon} = -2\frac{da}{a} + 2\cos 2\varphi\, df$, where a = equatorial radius, φ the latitude, and $2f = e^2 = \frac{a^2-b^2}{a^2}$, as given in Part I, p. 52.

covered by the ordinary and inherent probable errors of observation. What has been done was a recomputation of the geographical positions, by the same formulæ as before but with the changed constants, the distances and angles of triangles remaining unchanged; in other words, the strip of triangulation was simply transferred to and developed upon the other spheroid. Part of this special computation was made differentially. An essential and necessary feature, however, is the relation of the standard position and azimuth of the central station "Hays" in the two computations.

D. COMPARISON OF ASTRONOMIC AND STANDARD GEODETIC DATA ON THE SPHEROIDS OF CLARKE AND BESSEL.

1. COMPARISON OF ASTRONOMIC AND STANDARD GEODETIC LATITUDES DEVELOPED UPON THE SPHEROIDS OF CLARKE AND BESSEL.

No.	Name of astronomic station.	Observed astronomic latitude.	Seconds of geodetic latitude, Clarke's spheroid	Seconds of geodetic latitude, Bessel's spheroid	A − G Clarke	A − G Bessel
		° ′ ″	″	″	″	″
1	Cape May	38 55 44·03	45·53	44·23	1·50	0·20
2	Cape Henlopen	38 46 40·07	39·08	38·64	+ 0·99	1·43
3	Dover	39 09 13·47	18·59	17·42	5·12	3·95
4	Principio	39 35 32·75	34·55	33·57	1·80	0·82
5	Poole Island	39 17 17·52	13·52	12·47	4·00	5·05
6	Calvert	38 21 31·71	32·17	30·84	0·46	0·87
7	Taylor	38 59 46·07	46·34	45·22	0·27	0·85
8	Marriott	38 52 25·05	25·68	24·54	0·63	+ 0·51
9	Webb	39 05 25·35	24·16	23·09	+ 1·19	+ 2·26
10	Hill	38 53 52·36	52·24	51·12	+ 0·12	+ 1·24
11	Soper	39 05 10·61	09·80	08·76	+ 0·81	1·85
12	Seaton	38 53 25·12	26·82	25·72	1·70	0·60
13	Coast and Geodetic Survey Office, observatory	38 53 07·35	10·00	08·89	2·65	1·54
14	United States Naval Observatory (old), dome	38 53 38·78	40·12	39·02	1·34	0·24
15	United States Naval Observatory (new), clock room	38 55 13·74	14·89	13·80	1·15	0·06
16	Causten	38 55 32·02	32·81	31·72	0·79	+ 0·30
17	Georgetown College, Observatory	38 54 25·79	27·80	26·71	2·01	0·92
18	Rockville	39 05 10·42	09·08	08·05	+ 1·34	+ 2·37
19	Sugar Loaf	39 15 49·54	43·65	42·70	+ 5·89	+ 6·84
20	Maryland Heights	39 20 32·19	26·30	25·41	+ 5·89	+ 6·78
21	Bull Run	38 52 56·72	52·08	51·04	+ 4·64	+ 5·68
22	Strasburg	38 59 31·56	27·82	26·87	+ 3·74	+ 4·69
23	Clark Mountain	38 18 39·60	39·22	38·03	+ 0·38	1·57
24	Charlottesville, University Transit	38 01 61·09	55·92	54·69	+ 5·17	+ 6·40
25	Long Mountain	37 17 28·84	25·50	24·09	+ 3·34	+ 4·75
26	Elliott Knob	38 09 57·08	57·51	56·39	0·43	+ 0·69

I. COMPARISON OF ASTRONOMIC AND STANDARD GEODETIC LATITUDES DEVELOPED UPON THE SPHEROIDS OF CLARKE AND BESSEL—Continued.

No.	Name of astronomic station.	Observed astronomic latitude.	Seconds of geodetic latitude, Clarke's spheriod.	Seconds of geodetic latitude, Bessel's spheriod.	(A-G) Clarke.	(A-G) Bessel.
		° ′ ″	″	″	″	″
27	Keeney	37 46 23·07	23·52	22·39	− 0·45	+ 0·68
28	Charleston	38 20 66·95	60·23	59·36	+ 6·72	+ 7·59
29	Piney	38 26 41·40	37·97	37·16	+ 3·43	+ 4·24
30	Gould	38 38 29·78	27·54	26·85	+ 2·24	+ 2·93
31	Minerva	38 42 30·89	29·14	28·54	+ 1·75	+ 2·35
32	Mount Lookout Observatory, dome	39 08 19·65	18·91	18·49	+ 0·74	+ 1·16
33	Reizin	39 02 53·76	51·84	51·43	+ 1·92	+ 2·33
34	Weed Patch	39 09 60·68	58·66	58·35	+ 2·02	+ 2·33
35	Vincennes	38 40 36·80	33·75	33·36	+ 3·05	+ 3·44
36	Parkersburg, Triangulation Station	38 34 53·05	49·58	49·19	+ 3·47	+ 3·86
37	Olney West Base	38 51 41·28	36·63	36·33	+ 4·65	+ 4·95
38	Newton	38 55 31·10	26·65	26·38	+ 4·45	+ 4·72
39	Bording	38 36 50·93	43·40	43·08	+ 7·53	+ 7·85
40	St. Louis University, Second Presbyterian Church	38 37 60·59	54·30	54·02	+ 6·29	+ 6·57
41	Jefferson City	38 33 43·95	39·32	39·10	+ 4·63	+ 4·85
42	Hunter	38 25 48·00	43·38	43·13	+ 4·62	+ 4·87
43	Kansas City	39 05 51·12	48·62	48·63	+ 2·50	+ 2·49
44	Adams	39 02 41·80	39·28	39·30	+ 2·52	+ 2·50
45	Salina West Base	38 51 03·52	05·97	05·94	− 2·45	− 2·42
46	Ellsworth	38 43 47·49	47·07	47·01	+ 0·42	+ 0·48
47	Russell Southeast	38 51 22·73	20·63	20·61	+ 2·10	+ 2·12
48	Wallace	38 54 44·25	42·75	42·74	+ 1·50	+ 1·51
49	Adobe	38 40 37·42	39·30	39·19	− 1·88	− 1·77
50	El Paso East Base	38 57 16·50	20·84	20·64	− 4·34	− 4·14
51	Colorado Springs (1873)	38 49 59·98	61·74	61·65	− 1·76	− 1·67
52	Pikes Peak	38 50 27·28	24·82	24·72	+ 2·46	+ 2·56
53	Mount Ouray	38 25 18·00	21·40	21·14	− 3·40	− 3·14
54	Treasury Mountain	39 00 47·25	49·68	49·58	− 2·43	− 2·33
55	Gunnison, Colorado	38 32 44·39	45·65	45·40	− 1·26	− 1·01
56	Uncompahgre	38 04 15·74	16·71	16·30	− 0·97	− 0·56
57	Grand Junction	39 03 59·04	53·84	53·70	+ 5·20	+ 5·34
58	Tavaputs	39 32 17·12	23·20	23·19	− 6·08	− 6·07
59	Mount Waas	38 32 29·00	19·22	18·88	+ 9·78	+10·12
60	Green River	38 59 23·63	28·95	28·71	− 5·32	− 5·08
61	Patmos Head	39 29 56·86	69·05	68·96	−12·19	−12·10
62	Mount Ellen	38 07 24·17	15·33	14·79	+ 8·84	+ 9·38
63	Wasatch	39 06 53·83	56·13	55·86	− 2·30	− 2·03
64	Mount Nebo	39 48 32·31	37·24	37·18	− 4·93	− 4·87

I. COMPARISON OF ASTRONOMIC AND STANDARD GEODETIC LATITUDES DEVELOPED UPON THE SPHEROIDS OF CLARKE AND BESSEL—Continued.

No.	Name of astronomic station.	Observed astronomic latitude.	Seconds of geodetic latitude, Clarke's spheroid.	Seconds of geodetic latitude Bessel's spheroid.	(A-G) Clarke.	(A-G) Bessel.
		° ′ ″	″	″	″	″
65	Gunnison, Utah	39 09 25 ·46	29 ·76	29 ·49	− 4 ·30	− 4 ·03
66	Ogden Peak	41 11 59 ·22	59 ·50	59 ·89	− 0 ·28	− 0 ·67
67	Salt Lake City	40 46 03 ·36	11 ·10	11 ·35	− 7 ·74	− 7 ·99
68	Ogden Observatory, longitude pier	41 13 08 ·33	11 ·27	11 ·66	− 2 ·94	− 3 ·33
69	Waddoup	40 54 21 ·73	22 ·72	23 ·01	− 0 ·99	− 1 ·28
70	Antelope	40 57 40 ·16	42 ·78	43 ·07	− 2 ·62	− 2 ·91
71	Promontory	41 17 47 ·77	52 ·42	52 ·81	− 4 ·65	− 5 ·04
72	Deseret	40 27 31 ·25	33 ·74	33 ·84	− 2 ·49	− 2 ·59
73	Beaver	38 16 22 ·90	24 ·37	23 ·77	− 1 ·47	− 0 ·87
74	Oasis	39 17 35 ·29	36 ·70	36 ·42	− 1 ·41	− 1 ·13
75	Ibepah	39 49 38 ·97	41 ·47	41 ·28	− 2 ·50	− 2 ·31
76	Pilot Peak	41 01 07 ·83	15 ·98	16 ·18	− 8 ·15	− 8 ·35
77	Pioche	37 59 06 ·80	09 ·98	09 ·20	− 3 ·18	− 2 ·40
78	Pioche United States Engineer's Station	37 55 25 ·80	37 ·34	36 ·52	−11 ·54	−10 ·72
79	Diamond Peak	39 35 03 ·65	06 ·05	05 ·65	− 2 ·40	− 2 ·00
80	Mount Callahan	39 42 31 ·92	34 ·31	33 ·86	− 2 ·39	− 1 ·94
81	Toiyabe Dome	38 49 53 ·91	58 ·41	57 ·65	− 4 ·50	− 3 ·74
82	Carson Sink	39 34 57 ·67	59 ·64	59 ·05	− 1 ·97	− 1 ·38
83	Carson City, observatory, Z. T.	39 09 47 ·25	51 ·24	50 ·38	− 3 ·99	− 3 ·13
84	Verdi	39 31 04 ·29	05 ·11	04 ·35	− 0 ·82	− 0 ·06
85	Lake Tahoe, Southeast	38 57 19 ·37	15 ·71	14 ·77	+ 3 ·66	+ 4 ·60
86	Mount Conness	37 57 55 ·98	58 ·23	57 ·04	− 2 ·25	− 1 ·06
87	Round Top	38 39 46 ·27	49 ·31	48 ·27	− 3 ·04	− 2 ·00
88	Mount Lola	39 25 57 ·37	59 ·30	58 ·47	− 1 ·93	− 1 ·10
89	Mocho	37 28 36 ·71	38 ·76	37 ·21	− 2 ·05	− 0 ·50
90	Marysville	39 08 12 ·27	18 ·71	17 ·67	− 6 ·44	− 5 ·40
91	Mount Hamilton, Lick Observatory, Coast and Geodetic Astronomic Station	37 20 28 ·85	33 ·87	32 ·27	− 5 ·02	− 3 ·42
92	Yolo Base Southeast	38 31 34 ·55	41 ·70	40 ·45	− 7 ·15	− 5 ·90
93	Yolo Base Northwest	38 40 37 ·25	44 ·01	42 ·80	− 6 ·76	− 5 ·55
94	Mount Diablo	37 52 49 ·60	54 ·52	53 ·06	− 4 ·92	− 3 ·46
95	Vaca	38 22 23 ·27	32 ·52	31 ·19	− 9 ·25	− 7 ·92
96	Monticello	38 39 46 ·26	50 ·04	48 ·79	− 3 ·78	− 2 ·53
97	San Francisco, Washington Square	37 47 56 ·90	63 ·80	62 ·26	− 6 ·90	− 5 ·36
98	San Francisco, Lafayette Park	37 47 28 ·31	31 ·01	29 ·47	− 2 ·70	− 1 ·16
99	San Francisco, Presidio, old	37 47 35 ·96	38 ·24	36 ·70	− 2 ·28	− 0 ·74
100	San Francisco, Presidio, new	37 47 48 ·35	50 ·47	48 ·93	− 2 ·12	− 0 ·58

1. COMPARISON OF ASTRONOMIC AND STANDARD GEODETIC LATITUDES DEVELOPED UPON THE SPHEROIDS OF CLARKE AND BESSEL—Completed.

No.	Name of astronomic station.	Observed astronomic latitude.	Seconds of geodetic latitude, Clarke's spheroid.	Seconds of geodetic latitude Bessel's spheroid.	(A–G) Clarke.	(A–G) Bessel.
		° ′ ″	″	″	″	″
101	Mount Tamalpais	37 55 19·18	26·65	25·13	− 7·47	− 5·95
102	Mount Helena	38 40 01·05	09·23	07·94	− 8·18	− 6·89
103	Ross Mountain	38 30 09·96	19·70	18·31	− 9·74	− 8·35
104	Sulphur Peak	38 45 44·42	53·38	52·10	− 8·96	− 7·68
105	Ukiah	39 08 54·59	58·00	56·80	− 3·41	− 2·21
106	Point Reyes	37 59 33·62	43·41	41·88	− 9·79	− 8·26
107	Bodega	38 18 20·11	28·96	27·52	− 8·85	− 7·41
108	Mendocino City	39 18 05·50	12·60	11·39	− 7·10	− 5·89
109	Point Arena	38 55 10·16	18·07	16·75	− 7·91	− 6·59

2. COMPARISON OF ASTRONOMIC AND STANDARD GEODETIC AZIMUTHS ON THE SPHEROIDS OF CLARKE AND BESSEL.

No.	Station occupied.	Station referred to.	Observed astronomic azimuth west of south.	Seconds of geodetic azimuth, Clarke's spheroid.	Seconds of geodetic azimuth, Bessel's spheroid.	(A–G) Clarke.	(A–G) Bessel.
			° ′ ″	″	″	″	″
1	Cape Henlopen Light	Brandywire Shoal Light-house	173 45 17·64	15·29	22·95	+ 2·35	− 5·31
2	Principio	Turkey Point	1 34 43·50	34·58	42·05	+ 8·92	+ 1·45
3	Calvert	Meekin Neck	252 06 09·18	00·81	08·04	+ 8·37	+ 1·14
4	Marriott	Hill	96 37 43·40	35·04	42·25	+ 8·36	+ 1·15
5	Webb	Soper	88 59 49·38	42·70	49·91	+ 6·68	− 0·53
6	Hill	Webb	219 46 58·11	51·13	58·26	+ 6·98	− 0·15
7	Soper	Webb	268 49 23·60	18·14	25·26	+ 5·46	− 1·66
8	Seaton	Hill	265 32 53·61	43·55	50·64	+10·06	+ 2·97
9	Causten	Soper	210 54 41·65	37·58	44·65	+ 4·07	− 3·00
10	Sugar Loaf	Bull Run	32 29 16·97	22·28	29·30	− 5·31	−12·33
11	Maryland Heights	Bull Run	358 43 07·18	10·54	17·46	− 3·36	−10·28
12	Bull Run	Peach Grove	263 53 28·49	30·60	37·48	− 2·11	− 8·99
13	Clark Mount	Bull Run	202 19 27·98	28·81	35·55	− 0·83	− 7·57
14	Long Mount	Spear	223 28 41·64	46·66	52·99	− 5·02	−11·35
15	Elliott Knob	Humpback	303 25 24·46	22·28	28·62	+ 2·18	− 4·16
16	Keeney	Bald Knob	257 04 35·89	33·77	39·65	+ 2·12	− 3·76
17	Piney	Gebhardt	119 04 31·84	32·69	38·22	− 0·85	− 6·38
18	Gould	Howland	84 49 13·61	11·27	16·57	+ 2·34	− 2·96
19	Minerva	Ash Ridge	210 54 42·38	47·60	52·54	− 5·22	−10·16
20	Reizin	Tanner	276 56 46·02	48·99	53·56	− 2·97	− 7·54
21	Weed Patch	Fountain	7 33 21·28	22·01	26·25	− 0·73	− 4·97
22	Osborn	Calvary	192 16 17·59	18·34	22·36	− 0·75	− 4·77
23	Parkersburg	Denver	143 16 15·55	17·21	20·85	− 1·66	− 5·30
24	Newton	Claremont	321 29 05·30	06·20	09·82	− 0·90	− 4·52
25	Bording	Geoffrey	53 25 07·53	05·77	09·00	+ 1·76	− 1·47
26	Kleinschmidt	Insane Asylum	200 09 31·81	30·73	33·66	+ 1·08	− 1·85
27	Berger	Winter	39 12 05·64	03·05	05·67	+ 2·59	− 0·03
28	Jefferson City	Cedar	199 55 37·47	35·93	38·26	+ 1·54	− 0·79

2. COMPARISON OF ASTRONOMIC AND STANDARD GEODETIC AZIMUTHS ON THE SPHEROIDS OF CLARKE AND BESSEL—Completed.

No.	Station occupied.	Station referred to.	Observed astronomic azimuth west of south.	Seconds of geodetic azimuth, Clarke's spheroid.	Seconds of geodetic azimuth, Bessel's spheroid.	(A–G) Clarke.	(A–G) Bessel.
			° ′ ″	″	″	″	″
29	Hunter	Christian	221 48 20·49	23·17	25·31	− 2·68	− 4·82
30	Adams	Clark	11 46 11·94	12·39	13·45	− 0·45	− 1·51
31	Salina West Base	Salina East Base	248 36 18·32	24·22	24·78	− 5·90	− 6·46
32	Russell Southeast	Russell Northwest	140 42 59·79	67·9	68·07	− 8·11	− 8·28
33	Overland	Eureka	284 10 32·62	33·61	32·30	− 0·99	+ 0·32
34	El Paso East Base	El Paso West Base	102 48 04·62	03·24	01·51	+ 1·38	+ 3·11
35	Pikes Peak	Mount Ouray	66 05 16·70	11·04	09·14	+ 5·66	+ 7·56
36	Mount Ouray	Uncompahgre	70 35 51·27	54·27	51·99	− 3·00	− 0·72
37	Gunnison, Colorado	Uncompahgre	41 55 00·39	11·72	09·22	−11·33	− 8·83
38	Treasury Mountain	Mount Waas	74 45 04·71	18·28	15·71	−13·57	−11·00
39	Uncompahgre	Treasury Mountain	196 42 55·84	64·10	61·44	− 8·26	− 5·60
40	Grand Junction	Chiquita	23 57 23·98	31·93	28·88	− 7·95	− 4·90
41	Tavaputs	Patmos Head	88 17 40·85	46·95	43·73	− 6·10	− 2·88
42	Mount Waas	Mount Ellen	72 00 16·62	30·65	27·41	−14·03	−10·79
43	Patmos Head	Wasatch	66 41 18·70	29·77	26·13	−11·07	− 7·43
44	Mount Ellen	Patmos Head	195 35 57·89	64·46	60·72	− 6·57	− 2·83
45	Wasatch	Mount Nebo	160 54 02·73	12·28	08·28	− 9·55	− 5·55
46	Mount Nebo	Tushar	20 05 23·06	41·11	36·97	−18·05	−13·91
47	Salt Lake City	City Creek	192 02 50·50	68·67	64·43	−18·17	−13·93
48	Waddoup	Ogden Peak	180 42 32·55	56·58	52·34	−24·03	−19·79
49	Ogden Observatory	Ogden Peak	283 08 44·70	61·47	57·17	−16·77	−12·47
50	Ogden Peak	Mount Nebo	356 19 30·37	44·25	40·00	−13·88	− 9·63
51	Antelope	Deseret	31 59 04·14	13·59	09·23	−09·45	− 5·09
52	Promontory	Ogden Peak	283 23 62·64	63·07	58·62	− 0·43	+ 4·02
53	Deseret	Mount Nebo	314 14 01·38	14·72	10·24	−13·34	− 8·86
54	Ibepah	Diamond Peak	81 11 28·49	36·26	31·40	− 7·77	− 2·91
55	Pioche	Tushar	250 58 50·29	58·55	53·80	− 8·26	− 3·51
56	Pilot Peak	Mount Nebo	303 40 14·15	19·19	14·19	− 5·04	− 0·04
57	Diamond Peak	Mount Callahan	98 27 13·82	19·66	14·23	− 5·84	− 0·41
58	Mount Callahan	Carson Sink	83 09 34·84	42·00	36·19	− 7·16	− 1·35
59	Toiyabe Dome	Mount Grant	77 20 49·29	58·51	52·66	− 9·22	− 3·37
60	Carson Sink	Mount Callahan	262 20 25·50	31·32	25·11	− 5·82	+ 0·39
61	Mount Conness	Round Top	142 39 19·46	29·96	23·57	−10·50	− 4·11
62	Lake Tahoe Southeast	Folsom Peak	177 56 19·13	29·4	22·7	−10·3	− 3·6
63	Round Top	Mount Helena	90 58 53·89	59·84	53·18	− 5·95	+ 0·71
64	Mount Lola	Mount Helena	67 21 62·36	66·09	59·24	− 3·73	+ 3·12
65	Mocho	Mount Diablo	144 57 35·71	42·66	35·63	− 6·95	+ 0·08
66	Yolo Base Southeast	Yolo Base Northwest	163 07 13·11	21·65	14·45	− 8·54	− 1·34
67	Yolo Base Northwest	Yolo Base Southeast	343 05 02·07	10·60	03·38	− 8·53	− 1·31
68	Mount Diablo	Mount Helena	144 28 16·03	21·56	14·40	− 5·53	+ 1·63
69	Vaca	Yolo Base Southeast	235 38 36·55	39·99	32·72	− 3·44	+ 3·83
70	Monticello	Mount Helena	91 04 25·30	30·33	23·00	− 5·03	+ 2·30
71	Mount Tamalpais	Mount Diablo	274 15 15·04	22·13	14·76	− 7·09	+ 0·28
72	Mount Helena	Mount Diablo	324 01 24·96	37·52	30·06	−12·56	− 5·10
73	Paxton	Mount Sanhedrin	203 47 05·77	17·36	09·66	−11·59	− 3·89

3. COMPARISON OF ASTRONOMIC AND STANDARD GEODETIC LONGITUDES ON THE SPHEROIDS OF CLARKE AND BESSEL.

No.	Name of astronomic station.	Observed astronomic longitude.	Seconds of geodetic longitude, Clarke's spheroid.	Seconds of geodetic longitude, Bessel's spheroid.	(A–G) Clarke.	(A–G) Bessel.
		° ′ ″	″	″	″	″
1	Cape May, transit	74 55 45·68	48·03	35·43	− 2·35	+10·45
2	Dover	75 31 18·45	24·51	12·16	− 6·06	+ 6·29
3	Washington, Coast and Geodetic Survey Office, observatory transit	77 00 25·64	32·71	21·16	− 7·07	+ 4·48
4	Washington, old Naval Observatory, dome	77 02 62·30	66·68	55·15	− 4·38	+ 7·15
5	Washington, new Naval Observatory, clock room	77 03 56·76	62·80	51·27	− 6·04	+ 5·49
6	Strasburg	78 21 35·70	39·53	28·65	− 3·83	+ 7·05
7	Charlottesville, McCormick Observatory	78 31 20·10	21·15	10·50	− 1·05	+ 9·60
8	Charleston, West Virginia	81 37 61·95	59·64	50·52	+ 2·31	+11·43
9	Cincinnati, Mount Lookout Observatory, dome	84 25 20·97	21·72	13·94	− 0·75	+ 7·03
10	Vincennes	87 31 30·14	35·32	29·20	− 5·18	+ 0·94
11	Parkersburg, transit	88 01 48·30	49·27	43·42	− 0·97	+ 4·88
12	St. Louis, transit pier, Washington University	90 12 18·84	17·63	12·90	+ 1·21	+ 5·94
13	Kansas City	94 35 21·06	22·23	19·77	− 1·17	+ 1·29
14	Ellsworth	98 13 36·36	44·97	44·42	− 8·61	− 8·06
15	Wallace	101 35 25·96	31·41	32·62	− 5·45	− 6·66
16	Colorado Springs (1885)	104 49 10·65	34·55	37·45	−23·90	−26·80
17	Gunnison, Colorado	106 55 30·68	26·54	30·52	+ 4·14	+ 0·16
18	Grand Junction	108 33 54·02	53·16	58·03	+ 0·86	− 4·01
19	Green River	110 09 53·08	55·40	61·10	− 2·32	− 8·02
20	Salt Lake City	111 53 47·60	26·89	33·65	+20·71	+13·85
21	Ogden Observatory, longitude pier	111 59 55·59	37·54	44·40	+18·05	+11·19
22	Oasis	112 37 55·41	43·96	50·96	+11·45	+ 4·45
23	Eureka	115 57 37·56	30·24	39·00	+ 7·32	− 1·44
24	Austin	117 04 27·24	11·79	21·13	+15·45	+ 6·11
25	Virginia City	119 38 42·08	49·52	60·16	− 7·44	−18·08
26	Carson City, Observatory transit	119 45 44·60	48·59	59·27	− 3·99	−14·67
27	Genoa	119 50 22·34	45·92	56·62	−23·58	−34·28
28	Lake Tahoe Southeast.	119 56 45·90	40·60	51·34	+ 5·30	− 5·44
29	Verdi	119 58 52·90	57·68	68·53	− 4·78	−15·63
30	Sacramento	121 29 35·80	30·04	41·51	+ 5·76	− 5·71
31	Marysville	121 35 17·79	09·88	21·49	+ 7·91	− 3·70
32	Mount Hamilton, Lick Observatory, transit house	121 38 43·42	30·42	41·77	+13·00	+ 1·65
33	San Francisco, Washington Square	122 24 36·62	31·11	42·92	+ 5·51	− 6·30
34	San Francisco, Lafayette Park	122 25 42·92	36·82	48·64	+ 6·10	− 5·72
35	San Francisco, new Presidio	122 27 12·20	04·83	16·66	+ 7·37	− 4·46
36	Ukiah	123 12 33·51	27·60	40·04	+ 5·91	− 6·53
37	Point Arena	123 41 46·26	23·96	36·60	+22·30	+ 9·66

Scrutinizing the preceding tabular results expressing the deviations of the astronomic and geodetic results, for the two representative spheroids, and beginning with the latitudes, we notice that the figures in the last two columns easily fall into three groups. In the first group of 19 values, between the Atlantic coast and the eastern flank of the Blue Ridge, the deflections are small and changing sign; in the second group of 29 values, from the Blue Ridge to western Kansas, the plus sign is largely predominating, and in the third group of 61 values, from western Kansas to the Pacific coast, the opposite sign subsists. The average deviations are as below:

		C.	B.
		$''$	$''$
Group 1, stations 1 to 19	$\frac{1}{19}\Sigma(A-G) =$	$-0 \cdot 34$	$+0 \cdot 77$
Group 2, stations 20 to 48	$\frac{1}{29}\Sigma(A-G) =$	$+2 \cdot 29$	$+3 \cdot 52$
Group 3, stations 49 to 109	$\frac{1}{61}\Sigma(A-G) =$	$-3 \cdot 69$	$-2 \cdot 89$

Thus, over the great extent of the second group, the average surface of the geoid (in the region of the thirty-ninth parallel) seems to be tilted toward the north 2 or 3 seconds, whereas in the third group, covering the region across the Rocky Mountains, the tilt of the geoid is opposite and toward the south about 3 seconds. These deformations are well marked and afford us a glimpse of their vast extent, though at present we have no means of tracing them to the north or south beyond our parallel. Squaring the differences $(A-G)$ and summing up, we find for the spheroids for $(C.)$, 2 389 and for $(B.)$, 2 163. The difference is small, as might have been expected from the small excursions beyond latitude 39° and is in favor of the Besselian spheroid.

The *azimuthal* comparisons exhibit much larger differences than the preceding ones. We have $\Sigma(A-G)^2 = 4\,895$ for (C) and 2 888 for (B) and after rejecting 8 stations, all west of Pikes Peak, where the deflections exceed 13 seconds, the above figures become 2 813 and 1 665, respectively, in favor of *B's* spheroid. It is different with the *longitudinal* comparisons; here we have $\Sigma(A-G)^2 = 3\,674$ for (C) and 4 186 for (B) and after rejecting 5 values, at Colorado Springs and 4 stations west of it, where the deflections exceed 18 seconds, we find 1 294 and 1 882, respectively, in either case in favor of Clarke's spheroid. In a general way the tabular values of $(A-G)$ in the last two columns appear in opposition respecting their sign, and near the Atlantic side of the arc the negative signs for $(C.)$ predominate; near the Pacific side the positive signs prevail. This last remark, as has already been stated, is in conformity with the fact of the prevalence of opposite signs in the $(C.)$ columns of $(A-G)$ of the azimuthal and longitudinal tables. We have for the azimuthal stations Nos. 1 to 9 the mean value $\frac{1}{9}\Sigma(A-G) = +6''\cdot 8$, which converted into longitudinal difference by $\delta\lambda = -\delta\alpha \operatorname{cosec} \alpha$, equals $-10''\cdot 8$, the mean tabular difference is $-5''\cdot 2$; on the Pacific side we have the mean of 8 values (Nos. 66–73) of $(A-G)$ from azimuths $-7''\cdot 8$ corresponding to $+12''\cdot 4$ in longitude; the mean tabular difference (Nos. 30 to 39) is $+9''\cdot 2$.

E. REVIEW OF THE STATIONS EXHIBITING LARGE LOCAL DEFLECTIONS OF THE PLUMB LINE IN THE PLANE OF THE PRIME VERTICAL OR IN LONGITUDE.

The effect of the local disturbing action on the direction of the vertical at a station, due to irregularities of distribution and of density of the surrounding masses, may be approximately ascertained, provided we possess a contoured map of proper scale and extent of the region. Even with this knowledge the actual magnitude of the deflections must to a large extent remain uncertain, mainly owing to the defects of our reference spheroid and to our ignorance of the underground distribution of the masses and their density.*

At present we possess but very scanty knowledge respecting the surface configuration and distribution of matter at and in the vicinity of our longitude stations; yet it will be desirable to examine somewhat in detail, at stations exhibiting large deviations from the normal, how far the visible topographic environment may account for or support the observed deflections. Owing to the heterogeneous nature of the earth's crust, computations of this kind have not been very successful; although in cases of obvious influence a fair agreement between observed and computed deflection in sign and magnitude is generally brought out.

What will be needed by the computer, at least for stations showing large deflections, is a rough topographic survey covering the region for tens of kilometres, the extent depending upon local circumstances; the map to give the elevations by contour lines at suitable vertical intervals as between 50 and 100 or more metres.

Of stations exhibiting large east or west deflections—say, between about 20″ and 30″—Colorado Springs, Colorado, and Genoa, Nevada, hold first rank. Both places face an *eastern* flank of mountains which rise to a considerable height. Here $(A-G)$ is negative; hence the plumb line is largely deflected *westward.*

There are about 6 other stations with less, but still large, deflections with their $(A-G)$ positive, showing the plumb line deflection to be easterly. They are Point Arena, California; Salt Lake City, Ogden, and Oasis, Utah; Austin, Nevada, and Mount Hamilton, California.

1. At *Colorado Springs* the local configuration is as follows: Elevation of the station above the sea 1 822 metres (or 5 978 feet); elevation of Pikes Peak 4 300 metres (or 14 108 feet). Pikes Peak is west of Colorado Springs 18½ kilometres (or 11½ statute miles). A profile through the station and looking westward shows a plateau at an elevation of about 10 500 feet and extending from 60 to 80 miles, where it reaches the continental watershed or divide. The distribution and form of these masses are so very irregular that no representative geometric figure could be substituted to determine

* NOTE BY THE EDITOR.—The effect of a mountain on the direction of the plumb line was successfully calculated in the case of Haleakala, in the Hawaiian Islands. Utilizing the contours furnished by the Government Survey, the attraction was determined, at the station "Kaupo," by the formula—

$$A = \delta \int_{a_1}^{a_2} \int_{r_1}^{r_2} \int_{0}^{h} \frac{r^2 \cos. a \, da \, dr \, dz}{(r^2 + z^2)^{3/2}}$$

to be 27″·9. The latitude of this point was found by astronomical observations, and a similar determination was made for a point on the other side of the mountain. The two stations being connected by triangulation, a deflection of the plumb line at "Kaupo" of 29″·4 was revealed. Here we have a discrepancy of only 1″·5 between the two determinations. The mountain is 10 000 feet high and about 80 miles in circumference at the base. See Coast and Geodetic Survey Report for 1888, Appendix No. 14, page 529.

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roughly the amount of deflection. Supposing an attracting mass, cone-shaped, with height 2 478 metres and a base of 30 kilometres radius, density 2·3 and distance 18½ kilometres, the angular deflection would be nearly 22 seconds.

2. The station *Genoa* is located at the foot of the steep slope of a spur of mountains extending along the eastern side of Lake Tahoe. For this locality we possess a map of the topographic survey by Lieut. G. M. Wheeler, United States Army, expedition of 1876–77, from which we take the following heights: Genoa, 4 801 feet; crest of range at Genoa Peak, 9 155 feet, and at Monument Peak, 10 035 feet; surface of Lake Tahoe, 6 202 feet (according to railroad reports 6 247). Here the physical hypsometric features lend themselves readily to simple mathematical treatment. Referring to Clarke's Geodesy, page 298, to the case of the attraction at a point P on the slope of a triangular section of a mountain range of indefinite extent, we get, on transforming the expression, when P is at the foot of the slope—

$$A = 6''\cdot 22 \left\{ \tfrac{1}{2}\,\text{base} \,.\, \sin 2\sigma' \log. \left(\frac{\text{base}}{\text{front slope}}\right)^2 + 2\sigma \,.\, \text{base} \,.\, \sin^2 \sigma' \right\}$$

where A the attraction in seconds, σ the inclination of the front and σ' that of the rear slope, assumed density of mass 2·3, and the unit of length being the statute mile. With base $= 6$ miles at the level of Genoa station, $\tan \sigma = \frac{0\cdot 908}{2\cdot 25}$; hence $\sigma = 22°$, and $\sigma' = 13°\cdot 6$; we get $A = 11''\cdot 5$. This, however, takes no account of the attraction of the range on the west side of the lake about 20 miles distant and rising at least to a height equal to that on the east side.

3. At *Salt Lake City*, which is at an elevation of 4 334 feet, we have to the westward for about 150 miles a tolerably level ground, nowhere rising much above 5 000 feet, whereas to the east an outer spur of the Wasatch Range rises to about 9 500 feet at a distance of about 12 miles. Farther east the Uintah Mountains are at a still higher elevation. These conditions account for the large deflection at this place.

4. *Ogden City* (observatory) is similarly situated as the above station. The elevation of the observatory is 1 338 metres (or 4 390 feet), and that of Ogden Peak 2 924 metres (or 9 592 feet), which point is but 9·689 kilometres distant from the observatory. The difference in height is 1 586 metres (or 5 203 feet). To the west we have the Salt Lake, with Promontory Ridge (about 6 500 to 7 000 feet high) jutting into it, while to the east the closeness of the steep flank of the Wasatch Range and the elevated plateau over 7 000 feet in height farther to the east must exert a powerful influence on the vertical at the observatory.

5. The station *Oasis*, at an altitude of about 1 387 metres (or 4 550 feet), is situated near the Sevier River and in the desert of that name. To the west the desert extends many miles, but little of it is known except some minor elevations 1 000 or 2 000 feet above the general level; but at a distance of 60 kilometres (or 37¼ miles) the Antelope Mountain rises to 2 959 metres (or 9 708 feet). Eastward of the station the Canon Mountains culminate at the Point Scipio with an altitude of 2 967 metres (or 9 734 feet), which point lies at a distance of about 38 kilometres (or 23½ statute miles). Here, then, we have to expect a differential, or much smaller, longitudinal deflection than in the above cases, where the attracting masses were much nearer the stations attracted.

6. *Austin City* is situated on a western slope rising from an elevation of about 5 000 feet at Reese River, 7 or 8 miles distant from Austin City, to its crest of about 8 500

feet elevation. Information is wanting to estimate the deflection, except that it must be to the east.

7. *Mount Hamilton*, upon which the Lick Observatory is located, is of comparatively low altitude, rising only to 1 287 metres (or 4 221 feet). The mountain is of conical shape with its western slope sinking into the Santa Clara Valley, which is here less than 100 feet above the ocean. From the north around by northeast to southeast the mountain is surrounded by closely packed masses rising to 3 000 feet or more and comprised within a radius of about 30 kilometres (or 18½ miles). The attraction of these masses is to some extent compensated by that of the western hills of the Coast Range, which to the west skirt the Pacific Ocean at a distance of about 75 kilometres (or 46½ miles) from the mountain. The elevation of the Coast Range is between 1 500 and 2 000 feet, but that of the Santa Cruz Mountains to the southwest reaches, at its culminating point, 1 157 metres (or 3 797 feet) and is distant 31 kilometres (or 19 miles). We may infer that at the Lick Observatory the vertical is not largely affected (plumb-line attracted to the eastward).

8. There remains for special examination the environment of *Point Arena*, the western terminal station of the arc and distant from the coast less than 4 kilometres (or 2·4 statute miles). The vertical at this place is under the direct influence of the attracting force of the mountains and hills of the Coast Range, which in the parallel of Point Arena has a total width between 120 and 130 kilometres (or 75 and 80 statute miles). Beyond this there is the low and wide valley of the Sacramento River. The Coast Range consists of a series of parallel ridges trending approximately northwest and southeast. The first of these rises to 834 metres at Cold Spring and to 674 metres at Walalla and to about 754 metres (or 2 474 feet) at a distance of 20 kilometres (or 12½ miles); the second ridge reaches at Sanel Mountain an altitude of 1 022 metres (or 3 353 feet) and is distant from the coast 44 kilometres (or 27 miles). At this station we may therefore expect a considerable eastward deflection of the plumb line.

9. The next longitude station to the east, *Ukiah*, lies in the valley of the Russian River at an elevation above the sea between 250 and 300 metres. It is on the western side of the valley, which is here about 4 kilometres in width. A few kilometres to the west, at Paxton, the hills rise to 1 037 metres (or 3 403 feet); east of the station, the hills are of about the same height, except at the crossing of the main range, which lies at a greater altitude.

10. At *Marysville*, the distinctive feature of the landscape is the Butte, which lies westward about 20 kilometres (or 12½ miles) and reaches an altitude of 644½ metres (or 2 114 feet), while Marysville itself, on the other side of the Sacramento and Feather rivers, is but 20 metres (or 66 feet) above the sea. The greater proximity of the mountains on the east side of the valley, as compared with that on the west, probably more than offsets the attraction of the Butte.

The plumb line at stations in *San Francisco* or its immediate vicinity is probably but slightly disturbed from visible causes. The principal attracting mass along the parallel is Mount Diablo. Although 1 173 metres (or 3 849 feet) in height, its distance 45 kilometres (or 28 statute miles) is sufficient to greatly diminish its effect. To the west as far out as the bar, 17¾ kilometres (or 11 statute miles), we have shallow water, not exceeding 20 fathoms; beyond we reach depths of 100 fathoms at a distance of about 72 kilometres (or 44¾ statute miles) from San Francisco. The slope into deep water is therefore very different here from what it is off Point Arena.

F. SYNOPSIS OF RESULTS OF THE ASTRONOMIC AND CORRESPONDING GEODETIC MEASURES OF THE PARTS OF THE ARC.

1. PRELIMINARY STATEMENT.

There remains the presentation of the angular measures of the several longitudinal subdivisions of the arc, together with their corresponding linear measures. The latter is obtained by converting or redeveloping the geodetic differences of longitudes given in column 4 of the last table into their corresponding linear equivalents on the parallel of 39°, 1 degree in this latitude being equal to 86 628·62 metres for the Clarke spheroid. In the following table column 3 gives the differences of longitude counted from the easternmost station of the arc, as determined astronomically; column 4 shows the corresponding geodetic differences taken from the position computations as developed upon Clarke's spheroid, and the last column contains, by redevelopment, the corresponding linear distances on the parallel of 39°.

2. COMPARISON OF ASTRONOMIC AND GEODETIC LONGITUDES ON ARC OF PARALLEL ACROSS THE UNITED STATES.

TABLE A.

No.	Name of astronomic station.	Observed difference of longitude λ from initial eastern station.	Seconds of λ from triangulation.	Corresponding interval in metres on parallel of 39°.
		° ′ ″	″	m.
1	Cape May	0 00 00 ·00	00 ·00	0 ·0
2	Dover	0 35 32 ·77	36 ·48	51 411 ·2
3	Washington, Survey Office	2 04 39 ·96	44 ·68	180 107 ·6
4	Washington, Old Observatory	2 07 16 ·62	18 ·65	183 812 ·7
5	Washington, New Observatory.................	2 08 11 ·08	14 ·77	185 163 ·1
6	Strasburg	3 25 50 ·02	51 ·50	297 220 ·4
7	Charlottesville, observatory	3 35 34 ·42	33 ·12	311 216 ·2
8	Charleston	6 42 16 ·27	11 ·61	580 691 ·1
9	Cincinnati, observatory	9 29 35 ·29	33 ·69	822 338 ·8
10	Vincennes....................................	12 35 44 ·46	47 ·29	1 091 214 ·8
11	Parkersburg	13 06 02 ·62	01 ·24	1 134 864 ·8
12	St. Louis, University observatory	15 16 33 ·16	29 ·60	1 323 242 ·5
13	Kansas City	19 39 35 ·38	34 ·20	1 703 075 ·4
14	Ellsworth	23 17 50 ·68	56 ·94	2 018 373 ·2
15	Wallace	26 39 40 ·28	43 ·38	2 309 696 ·6
16	Colorado Springs	29 53 24 ·97	46 ·52	2 589 871 ·4
17	Gunnison, Colorado	31 59 45 ·00	38 ·51	2 771 598 ·7
18	Grand Junction	33 38 08 ·34	05 ·13	2 913 732 ·7
19	Green River	35 14 07 ·40	07 ·37	3 052 392 ·4
20	Salt Lake City................................	36 57 61 ·92	38 ·86	3 201 862 ·5
21	Ogden, observatory	37 03 69 ·91	49 ·51	3 210 781 ·7
22	Oasis	37 41 69 ·73	55 ·93	3 265 801 ·0
23	Eureka	41 01 51 ·88	42 ·21	3 554 233 ·0

TABLE A—Completed.

No.	Name of astronomic station.	Observed difference of longitude Δλ from initial eastern station.	Seconds of Δλ from triangulation.	Corresponding interval in metres on parallel of 39°.
24	Austin	42 08 41·56	23·76	3 650 524·3
25	Virginia City	44 42 56·40	61·49	3 873 778·9
26	Carson City, observatory	44 49 58·92	60·56	3 883 863·2
27	Genoa	44 54 36·66	57·89	3 891 018·1
28	Lake Tahoe Southeast	45 00 60·22	52·57	3 899 552·8
29	Verdi	45 03 07·22	09·65	3 902 851·5
30	Sacramento	46 33 50·12	42·01	4 033 573·2
31	Marysville	46 39 32·11	21·85	4 041 750·9
32	Mount Hamilton, Lick Observatory	46 42 57·74	42·39	4 046 576·6
33	San Francisco, Washington Square	47 28 50·94	43·08	4 113 008·5
34	San Francisco, Lafayette Park	47 29 57·24	48·79	4 114 589·7
35	San Francisco, New Presidio	47 31 26·52	16·80	4 116 707·5
36	Ukiah	48 16 47·83	39·57	4 182 226·9
37	Point Arena	48 45 60·58	35·93	4 224 009·8

The above Table A contains all that is needed of the results from the measurement of the arc in order that it may be available for combination with any other arc or arcs, either for the purpose of determining a local osculating spheroid, or a general one for the whole globe. It nevertheless appears desirable, for reasons already given, not to make such use of the arc measures in their entirety without some modification. Notwithstanding the large number of subdivisions of the arc, it is plain that certain stations affected with large *local* deflections in longitude could only be productive of injurious effects, and the same is to be said of stations closely crowded into a region having the same general deflection of the geoid.

In the following Table B these modifications have been made. The five stations, Colorado Springs ($\triangle\lambda$ about 24″), Salt Lake City ($\triangle\lambda$ about 21″), Ogden Observatory ($\triangle\lambda$ about 18″), Genoa ($\triangle\lambda$ about 24″), and Point Arena ($\triangle\lambda$ about 22″), are omitted and the three Washington stations are consolidated, as are also the three San Francisco stations, and their respective group means are placed in the new table:

3. RESULTS OF THE MEASUREMENT OF AN ARC OF PARALLEL ACROSS THE UNITED STATES IN LATITUDE 39°.

TABLE B.

No.	Name of astronomic station.	Observed astronomic difference of longitude west of initial station.	Corresponding geodetic linear measure of arc in metres.
		° ′ ″	m.
1	Cape May	0 00 00·00	0
2	Dover	0 35 32·77	51 411
3, 4, 5	Washington, District of Columbia (III)	2 06 42·55	183 028
6	Strasburg	3 25 50·02	297 220
7	Charlottesville, observatory	3 35 34·42	311 216
8	Charleston	6 42 16·27	580 691
9	Cincinnati, observatory	9 29 35·29	822 339
10	Vincennes	12 35 44·46	1 091 215
11	Parkersburg	13 06 02·62	1 134 865
12	St. Louis, University observatory	15 16 33·16	1 323 242
13	Kansas City	19 39 35·38	1 703 075
14	Ellsworth	23 17 50·68	2 018 373
15	Wallace	26 39 40·28	2 309 697
17	Gunnison, Colorado	31 59 45·00	2 771 599
18	Grand Junction	33 38 08·34	2 913 733
19	Green River	35 14 07·40	3 052 392
22	Oasis	37 42 09·73	3 265 801
23	Eureka	41 01 51·88	3 554 233
24	Austin	42 08 41·56	3 650 524
25	Virginia City	44 42 56·40	3 873 779
26	Carson, observatory	44 49 58·92	3 883 863
28	Lake Tahoe Southeast	45 01 00·22	3 899 553
29	Verdi	45 03 07·22	3 902 852
30	Sacramento	46 33 50·12	4 033 573
31	Marysville	46 39 32·11	4 041 751
32	Mount Hamilton, observatory	46 42 57·74	4 046 577
33, 34, 35	San Francisco (III)	47 30 04·90	4 114 769
36	Ukiah	48 16 47·83	4 182 227

If we divide the linear measures of the table by their corresponding angular amplitudes as expressed in degrees and fractions of a degree, we shall obtain the value of 1° on the arc directly resulting from measurement. Thus taking the whole arc or any part of it, we can compare the resulting length for 1° with its value on the Clarke spheroid 86 628·6 metres and with its value on the Bessel spheroid 86 616·0 metres. We select the following results:

	m.
Whole arc, Cape May to Point Arena (48°·766 828), Table A	1° = 86 616
Arc between Cape May and Ukiah (48°·279 953), Table B	624
Arc between Cape May and San Francisco (47°·501 361)	624
Arc between Washington, D. C., and San Francisco (45°·389 541)	622

Taking the first half or eastern part of the arc, we find—

	m.
For the part between Cape May and Wallace (26°·661 689)	86 630
And for the western part, Wallace to Ukiah (21°·618 264)	618

That is to say, the average curvature (in parallel 39°) of the surface of the geoid, for about four-sevenths of the arc, approaches closely that of the Clarke spheroid, while the actual curvature over the western or remaining three-sevenths part agrees better with that of the Besselian spheroid. The arc appears to demand an *intermediate spheroid*, of which, in latitude 39°, 1° equals nearly 86 624 metres, and which, therefore, favors that adopted by the Survey more than the older one.

We have yet to inquire into the accuracy of the linear measures of the partial arcs of Tables A and B. For this, provisions were made in Parts I and III, where the probable errors of the several parts of the triangulation are expressed in fractional parts of the distance covered. Thus we have for the Eastern Shore series in a length of 128 kilometres, the probable error developed in that length 2·1 metres; similarly in 12 kilometres across the Kent Island base net, 0·08 metre; in the 393 kilometres of the Allegheny series, 3·46 metres, etc. Adding these figures for the whole arc, we get 26·2 metres, which for 4 224 kilometres equals $\frac{1}{161\,000}$ part of the length. We may take this fraction to apply to any of the other tabular numbers. It is equivalent to a probable error of 6·2 millimetres per kilometre, or to 0·38 of an inch per statute mile. We may contrast this probable uncertainty of 26 metres in the length of the arc with the difference of length corresponding to 48°·77 of longitude on this parallel of 39° for the two spheroids under comparison. It is 12·61 metres × 48·77 or 615 metres, showing that the geodetic operation possesses abundant accuracy.

For the sake of completeness and reference, there follows a list of resulting geographic positions of the principal trigonometric stations of the triangulations pertaining to the measurement of the arc. Distances between the stations will be found in Parts I and III and azimuths are given in connection with the positions.

G. RESULTING GEOGRAPHIC POSITIONS AND AZIMUTHS OF THE PRINCIPAL TRIGONOMETRIC STATIONS, INCLUDING THE BASE NETS, BASED ON CLARKE'S SPHEROID OF 1866 AND THE STANDARD DATA OF THE ARC ACROSS THE UNITED STATES.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
New Jersey.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Cape May Light-House	38 55 56·625	74 57 39·144	103 27 41·58	283 13 50·01	Stone.
			150 50 37·66	330 43 57·78	Egg Island L. H.
Egg Island Light-House	39 10 41·645	75 08 13·798	39 59 56·23	219 52 42·63	Stone.
			90 22 36·73	270 12 36·92	Mahon.
Delaware.					
Cape Henlopen Light-House	38 46 39·418	75 05 03·518	139 31 50·10	319 22 38·90	Stone.
			211 54 33·74	31 59 12·52	Cape May L. H.
Brandywine Shoal Light-House	38 59 07·674	75 06 48·434	95 10 12·37	275 02 05·95	Stone.
			174 31 51·21	354 30 57·39	Egg Island L. H.
Stone	39 00 01·544	75 19 41·477	123 54 04·81	303 41 04·88	Hartley.
			162 26 33·56	342 23 48·50	Mahon.
Mahon	39 10 45·431	75 24 03·247	49 23 31·46	229 13 00·98	Kent.
			90 10 54·98	270 00 38·93	Hartley.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Delaware—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Hartley	39 10 46·708	75 40 18·400	1 30 00·17	181 38 53 52	Kent
			75 02 13·82	254 55 20 34	Barclay.
Kent	38 59 35·174	75 40 43·225	101 31 54·04	281 20 11 50	Hope.
			138 01 50·16	317 55 10 14	Barclay.
Maryland.					
Barclay	39 08 31·916	75 51 03·661	46 57 55·24	226 52 43 00	Hope
			138 58 26·28	318 51 06·21	Still Pond.
Hope	39 02 31·183	75 59 18·088	97 02 06·53	276 43 18·02	Linstid
			135 19 13·03	315 11 32 01	Clough.
Turkey Point	39 26 56·156	76 00 35·405	50 19 42 07	230 10 02 80	Pooles Island.
			94 21 30 60	274 11 00 07	Osbornes Ruin.
Still Pond	39 18 52·636	76 02 30·525	350 55 56·86	170 58 03·74	Hope.
			45 13 21·05	225 07 47 28	Clough.
Clough	39 12 04·350	76 11 27·913	64 00 12·52	243 49 02 43	Linstid.
			128 34 26·76	308 31 45·80	Finlay.
Pooles Island	39 17 05·681	76 15 49·954	41 27 16·64	221 18 51 52	Linstid.
			121 11 55·79	301 02 00 18	Finlay.
Swan Point	39 08 28·277	76 16 49·060	15 47 58·81	195 45 40 00	Kent Island N. Base.
			71 56 57·47	251 49 10·42	Linstid
Osbornes Ruin	39 27 52·796	76 16 53·430	355 38 26·43	175 39 06 70	Pooles Island.
			73 07 42·15	252 58 25 02	Finlay.
Kent Island North Base	38 58 24·429	76 20 27·924	64 41 00·08	244 30 52 03	Marriott.
			135 37 59·69	315 32 31·31	Linstid.
Kent Island South Base	38 53 51·787	76 21 58·789	82 53 40·15	262 44 20 64	Marriott.
			141 47 26·42	321 43 41·57	Taylor.
Taylor	38 59 46·243	76 27 56·483	42 39 34·28	222 34 07 07	Marriott.
			170 19 43·07	350 18 57 15	Linstid.
Linstid	39 05 19·591	76 29 09·376	24 16 04·75	204 11 23 07	Marriott.
			90 34 47·58	270 27 37 06	Webb.
Finlay	39 24 25·852	76 31 29·080	354 34 26·29	174 35 54 68	Linstid.
			20 18 03·46	200 12 20·76	Webb.
Marriott	38 52 25·417	76 36 35·724	96 37 35·04	276 27 23·21	Hill.
			166 46 12·26	346 43 44·44	Webb.
Webb	39 05 24·413	76 40 30·733	39 54 36·51	219 46 51·13	Hill.
			97 22 49·52	277 11 05 40	Stabler.
Hill	38 53 52·767	76 52 50·328	94 38 26·59	274 25 17 09	Peach Grove.
			159 55 24·59	339 51 47·46	Stabler.
Soper	39 05 09·703	76 57 01·286	268 49 18·14	88 59 42 70	Webb.
			343 50 29·38	163 53 07 29	Hill.
Stabler	39 07 15·569	76 59 07·050	43 31 30·39	223 22 16·17	Peach Grove.
			114 01 10·52	293 45 41 57	Sugar Loaf
Sugar Loaf	39 15 42·412	77 23 37·423	32 29 22·28	212 17 59 05	Bull Run.
			107 30 00·24	287 17 43 70	Maryland Heights.
Maryland Heights	39 20 25·561	77 43 00·445	358 43 10·54	178 43 40 58	Bull Run
			34 00 56·52	213 42 33·59	Mount Marshall.
Virginia.					
Peach Grove	38 55 10·601	77 13 47·327	84 11 21·80	263 53 59·60	Bull Run.
			159 34 44·78	339 28 32 60	Sugar Loaf
Bull Run	38 52 51·450	77 42 13·145	22 50 41 85	202 19 28 81	Clark
			75 02 38·38	254 43 51 26	Mount Marshall.
Clark	38 18 35·975	78 00 12·025	63 09 16·78	242 56 05 03	Humpback.
			117 25 51·89	297 10 26·09	Fork
Mount Marshall	38 46 31·658	78 12 10·813	341 17 18·02	161 24 45·90	Clark
			29 26 44 10	209 18 45 18	Fork
Fork	38 25 42·651	78 24 57·999	3 52 11·94	183 51 15 71	Humpback
			66 26 43 47	245 55 18 19	Elliott Knob.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Virginia—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Spear	37 33 40·751	78 45 47·192	90 43 50·62	270 28 12·08	Tobacco Row.
			164 25 09·04	344 20 08·66	Humpback.
Humpback	37 56 53·769	78 53 57·777	88 32 08·02	267 57 00·80	Bald Knob.
			123 40 43·29	303 25 22·28	Elliott Knob.
Slate Springs	38 30 33·579	79 11 04·196	16 37 49·95	196 32 59·87	Elliott Knob.
			63 18 24·00	242 55 36·21	Paddys Knob.
Tobacco Row	37 33 53·594	79 11 26·704	124 40 32·20	304 16 16·15	Bald Knob.
			211 01 07·74	31 11 50·01	Humpback.
Elliott Knob	38 09 57·225	79 18 51·841	60 37 08·94	240 17 17·38	Bald Knob.
			104 46 54·96	284 29 01·65	Paddys Knob.
Paddys Knob	38 15 54·637	79 47 46·831	7 19 03·04	187 17 00·61	Bald Knob.
			74 29 42·55	254 09 21·61	Briery.
Bald Knob	37 55 30·489	79 51 05·270	77 36 00·19	257 04 33·77	Keeney.
			119 24 57·24	299 06 43·18	Briery.
West Virginia.					
Briery	38 08 37·505	80 20 40·947	37 43 21·86	217 30 03·03	Keeney.
			81 15 41·10	261 06 01·66	Beech.
Beech	38 06 42·484	80 36 19·434	65 26 18·75	244 53 37·34	Ivy.
			129 17 11·11	309 07 24·42	Summersville.
Keeney	37 46 22·764	80 42 19·663	91 32 16·91	271 03 23·65	Ivy.
			193 08 02·49	13 11 43·98	Beech.
Summersville	38 16 53·283	80 52 08·216	45 04 22·46	224 41 21·91	Ivy.
			81 11 48·00	260 44 05·93	Table Rock.
Ivy	37 47 13·619	81 29 28·843	134 16 29·96	313 55 14·32	Pigeon.
			166 19 18·29	346 14 44·43	Table Rock.
Holmes	38 25 38·777	81 35 34·950	284 08 03·64	104 35 01·20	Summersville.
			4 07 38·28	184 06 49·41	Table Rock.
Table Rock	38 11 16·471	81 36 53·785	96 36 28·38	276 19 42·25	Pigeon.
			126 21 53·58	306 05 24·28	Piney.
Ryan	38 23 43·096	81 47 38·010	69 32 31·74	249 30 40·51	Rogers.
			147 12 04·18	327 10 19·12	Simms.
St. Albans East Base	38 22 40·516	81 47 42·671	94 09 23·88	274 07 35·57	Rogers.
			183 21 17·97	3 21 20·86	Ryan.
Coal	38 21 24·521	81 49 31·017	115 27 07·58	295 18 26·80	Piney.
			172 43 02·29	352 42 27·48	Simms.
St. Albans West Base	38 23 19·414	81 50 14·288	259 05 18·83	79 06 55·88	Ryan.
			288 02 20·58	108 03 54·72	St. Albans East Base.
Simms	38 27 09·349	81 50 27·055	32 05 46·11	212 02 38·06	Big Rocks.
			87 06 27·04	266 58 20·56	Piney.
Rogers	38 22 50·460	81 50 37·122	181 45 05·81	1 45 12·07	Simms.
			328 47 41·31	148 48 22·34	Coal.
Big Rocks	38 20 49·095	81 55 29·803	43 20 41·45	223 15 25·05	Pigeon.
			132 45 03·10	312 40 05·21	Piney.
Piney	38 26 37·533	82 03 29·424	68 22 17·96	248 11 17·52	Davis.
			119 04 32·69	298 57 15·79	Gebhardt.
Pigeon	38 13 41·992	82 04 00·448	118 36 42·27	298 26 02·62	Davis.
			181 48 07·59	1 48 26·83	Piney.
Gebhardt	38 31 43·604	82 15 11·468	23 59 26·24	203 55 41·64	Davis.
			112 00 34·96	291 52 48·78	Wray.
Davis	38 21 04·179	82 21 12·733	92 51 00·64	272 40 02·50	Oakland.
			160 53 59·50	340 49 58·99	Wray.
Ohio.					
Wray	38 35 40·196	82 27 39·318	32 25 48·02	212 18 48·66	Oakland.
			91 04 25·10	271 01 01·04	Fradd.
Fradd	38 35 44·880	82 33 06·440	44 56 56·41	224 47 26·47	Buena Vista.
			101 32 28·26	281 21 57·46	Gould.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Ohio—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Gould	38 38 25.541	82 49 57.127	355 09 37.02	175 10 36.22	Buena Vista.
			84 49 11.27	264 43 19.33	Howland.
Scioto	38 45 45.681	83 03 04.012	71 27 25.25	251 18 45.90	Twin Creek.
			118 36 27.77	298 24 45.66	Peach Mount.
Twin Creek	38 42 06.676	83 16 54.067	75 14 43.86	255 07 10.66	Cherry Ridge.
			161 57 03.98	341 54 02.43	Peach Mount.
Peach Mount	38 53 41.494	83 21 43.828	22 00 00.14	201 55 27.46	Cherry Ridge.
			76 05 09.49	255 56 16.41	Cave Hill.
Cave Hill	38 50 56.076	83 35 53.230	60 47 45.50	240 35 42.87	Minerva.
			119 54 00.03	299 48 02.70	Ash Ridge.
Ash Ridge	38 55 11.406	83 45 22.458	31 00 54.00	210 54 47.60	Minerva.
			94 04 00.33	273 49 46.10	Tate.
Tate	38 56 24.694	84 08 01.887	20 38 06.97	200 34 19.03	Flaugher.
			86 49 21.70	266 35 04.30	Stevens.
Kentucky.					
Oakland	38 21 44.421	82 38 53.293	104 45 38.95	284 39 45.82	Buena Vista.
			197 56 39.23	18 00 15.05	Fradd.
Buena Vista	38 23 41.984	82 48 22.071	125 23 32.55	305 13 34.08	Cave.
			148 30 35.92	328 23 45.74	Howland.
Howland	38 37 45.076	82 59 20.810	83 31 38.19	263 23 20.52	Round Top.
			160 01 09.73	339 58 50.19	Scioto.
Cave	38 32 37.696	83 04 24.094	121 19 19.31	301 14 11.21	Round Top.
			217 43 48.32	37 46 57.48	Howland.
Round Top	38 36 33.336	83 12 38.185	148 58 35.58	328 55 55.75	Twin Creek.
			219 07 23.80	39 13 22.69	Scioto.
Cherry Ridge	38 39 36.307	83 28 59.206	98 08 28.85	277 52 08.92	Minerva.
			154 32 15.59	334 27 36.42	Cave Hill.
Minerva	38 42 29.137	83 55 07.021	95 10 44.01	274 58 51.96	Flaugher.
			144 06 27.12	323 58 21.33	Tate.
Flaugher	38 43 48.420	84 14 05.385	79 02 20.46	258 49 28.21	Dry Ridge.
			131 40 30.84	311 30 03.29	Stevens.
Stevens	38 55 23.310	84 30 46.320	11 43 28.12	191 41 01.45	Dry Ridge.
			125 27 13.87	305 21 59.23	Tanner.
Dry Ridge	38 40 39.104	84 34 40.393	118 01 02.71	297 45 16.74	Stow.
			169 51 37.69	349 48 50.68	Tanner.
Tanner	39 00 01.058	84 39 06.701	61 14 23.14	241 01 21.18	Stow.
			97 15 15.73	276 56 48.99	Reizin.
Indiana.					
Stow	38 51 05.066	84 59 51.239	82 43 20.96	262 35 59.08	Culbertson.
			150 29 33.03	330 24 10.43	Reizin.
Reizin	39 02 51.861	85 08 24.409	10 53 43.71	190 51 43.42	Culbertson.
			73 48 24.32	253 42 59.55	Correct.
Culbertson	38 49 54.097	85 11 35.794	96 08 34.07	276 01 32.53	Mud Lick.
			159 02 41.82	338 59 18.05	Correct.
Correct	39 00 54.704	85 17 00.121	54 56 42.53	234 45 34.94	Stout.
			117 00 12.82	296 51 54.82	Green.
Glasgow	39 06 16.575	85 17 49.909	294 51 39.47	114 57 35.93	Reizin.
			353 07 07.87	173 07 39.24	Correct.
Holton South Base	39 01 48.934	85 22 03.521	175 53 48.57	355 53 38.25	Holton North Base.
			282 52 43.40	102 55 54.53	Correct.
Holton North Base	39 04 46.850	85 22 19.895	246 52 52.33	66 55 42.58	Glasgow.
			312 55 26.20	132 58 47.65	Correct.
Mud Lick	38 50 50.134	85 22 47.962	92 09 03.91	272 01 35.73	Stout.
			204 10 09.97	24 13 48.55	Correct.
Green	39 06 07.790	85 30 10.445	13 20 11.06	193 17 19.97	Stout.
			46 50 25.48	226 45 05.80	Tripp.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Virginia—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Spear	37 33 40·751	78 45 47·192	90 43 50·62	270 28 12·08	Tobacco Row.
			164 25 09·04	344 20 08·66	Humpback.
Humpback	37 56 53·769	78 53 57·777	88 32 08·02	267 57 00·80	Bald Knob.
			123 40 43·29	303 25 22·28	Elliott Knob.
Slate Springs	38 30 33·579	79 11 04·196	16 37 49·95	196 32 59·87	Elliott Knob.
			63 18 24·00	242 55 36·21	Paddys Knob.
Tobacco Row	37. 33 53·594	79 11 26·704	124 40 32·20	304 16 16·15	Bald Knob.
			211 01 07·74	31 11 50·01	Humpback.
Elliott Knob	38 09 57·225	79 18 51·841	60 37 08·94	240 17 17·38	Bald Knob.
			104 46 54·96	284 29 01·65	Paddys Knob.
Paddys Knob	38 15 54·637	79 47 46·831	7 19 03·04	187 17 20·61	Bald Knob.
			74 29 42·55	254 09 21·61	Briery.
Bald Knob	37 55 30·489	79 51 05·270	77 36 00·19	257 04 33·77	Keeney.
			119 24 57·24	299 06 43·18	Briery.
West Virginia.					
Briery	38 08 37·505	80 20 40·947	37 43 21·86	217 30 03·03	Keeney.
			81 15 41·10	261 06 01·66	Beech.
Beech	38 06 42·484	80 36 19·434	65 26 18·75	244 53 37·34	Ivy.
			129 17 11·11	309 07 24·42	Summersville.
Keeney	37 46 22·764	80 42 19·663	91 32 16·91	271 03 23·65	Ivy.
			193 08 02·49	13 11 43·98	Beech.
Summersville	38 16 53·283	80 52 08·216	45 04 22·46	224 41 21·91	Ivy.
			81 11 48·00	260 44 05·93	Table Rock.
Ivy	37 47 13·619	81 29 28·843	134 16 29·96	313 55 14·32	Pigeon.
			166 19 18·29	346 14 44·43	Table Rock.
Holmes	38 25 38·777	81 35 34·950	284 08 03·64	104 35 01·20	Summersville.
			4 07 38·28	184 06 49·41	Table Rock.
Table Rock	38 11 16·471	81 36 53·785	96 36 28·38	276 19 42·25	Pigeon.
			126 21 53·58	306 05 24·28	Piney.
Ryan	38 23 43·096	81 47 38·010	69 32 31·74	249 30 40·51	Rogers.
			147 12 04·18	327 10 19·12*	Simms.
St. Albans East Base	38 22 40·516	81 47 42·671	94 09 23·88	274 07 35·57	Rogers.
			183 21 17·97	3 21 20·86	Ryan.
Coal	38 21 24·521	81 49 31·017	115 27 07·58	295 18 26·80	Piney.
			172 43 02·29	352 42 27·48	Simms.
St. Albans West Base	38 23 19·414	81 50 14·288	259 05 18·83	79 06 55·88	Ryan.
			288 02 20·58	108 03 54·72	St. Albans East Base.
Simms	38 27 09·349	81 50 27·055	32 05 46·11	212 02 38·06	Big Rocks.
			87 06 27·04	266 58 20·56	Piney.
Rogers	38 22 50·460	81 50 37·122	181 45 05·81	1 45 12·07	Simms.
			328 47 41·31	148 48 22·34	Coal.
Big Rocks	38 20 49·095	81 55 29·803	43 20 41·45	223 15 25·05	Pigeon.
			132 45 03·10	312 40 05·21	Piney.
Piney	38 26 37·533	82 03 29·424	68 22 17·96	248 11 17·52	Davis.
			119 04 32·69	298 57 15·79	Gebhardt.
Pigeon	38 13 41·992	82 04 00·448	118 36 42·27	298 26 02·62	Davis.
			181 48 07·59	1 48 26·83	Piney.
Gebhardt	38 31 43·604	82 15 11·468	23 59 26·24	203 55 41·64	Davis.
			112 00 34·96	291 52 48·78	Wray.
Davis	38 21 04·179	82 21 12·733	92 51 00·64	272 40 02·50	Oakland.
			160 53 59·50	340 49 58·99	Wray.
Ohio.					
Wray	38 35 40·196	82 27 39·318	32 25 48·02	212 18 48·66	Oakland.
			91 04 25·10	271 01 01·04	Fradd.
Fradd	38 35 44·880	82 33 06·440	44 56 56·41	224 47 26·47	Buena Vista.
			101 32 28·26	281 21 57·46	Gould.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Ohio—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Gould	38 38 25.541	82 49 57.127	355 09 37.02	175 10 36.22	Buena Vista.
			84 49 11.27	264 43 19.33	Howland.
Scioto	38 45 45.681	83 03 04.012	71 27 25.25	251 18 45.90	Twin Creek.
			118 36 27.77	298 24 45.66	Peach Mount.
Twin Creek	38 42 06.676	83 16 54.067	75 14 43.86	255 07 10.66	Cherry Ridge.
			161 57 03.98	341 54 02.43	Peach Mount.
Peach Mount	38 53 41.494	83 21 43.8:8	22 00 00.14	201 55 27.46	Cherry Ridge.
			76 05 09.49	255 56 16.41	Cave Hill.
Cave Hill	38 50 56.076	83 35 53.230	60 47 45.50	240 35 42.87	Minerva.
			119 54 00.03	299 48 02.70	Ash Ridge.
Ash Ridge	38 55 11.406	83 45 22.458	31 00 54.00	210 54 47.60	Minerva.
			94 04 00.33	273 49 46.10	Tate.
Tate	38 56 24.694	84 08 01.887	20 38 06.97	200 34 19.03	Flaugher.
			86 49 21.70	266 35 04.30	Stevens.
Kentucky.					
Oakland	38 21 44.421	82 38 53.293	104 45 38.95	284 39 45.82	Buena Vista.
			197 56 39.23	18 00 15.05	Fradd.
Buena Vista	38 23 41.984	82 48 22.071	125 23 32.55	305 13 34.08	Cave.
			148 30 35.92	328 23 45.74	Howland.
Howland	38 37 45.076	82 59 20.810	83 31 38.19	263 23 20.52	Round Top.
			160 01 09.73	339 58 50.19	Scioto.
Cave	38 32 37.696	83 04 24.094	121 19 19.31	301 14 11.21	Round Top.
			217 43 48.32	37 46 57.48	Howland.
Round Top	38 36 33.336	83 12 38.185	148 58 35.58	328 55 55.75	Twin Creek.
			219 07 23.80	39 13 22.69	Scioto.
Cherry Ridge	38 39 36.307	83 28 59.206	98 08 28.85	277 52 06.92	Minerva.
			154 32 15.59	334 27 56.42	Cave Hill.
Minerva	38 42 29.137	83 55 07.021	95 10 44.01	274 58 51.96	Flaugher.
			144 06 27.12	323 58 21.33	Tate.
Flaugher	38 43 48.420	84 14 05.385	79 02 20.46	258 49 28.21	Dry Ridge.
			131 40 30.84	311 30 03.29	Stevens.
Stevens	38 55 23.310	84 30 46.320	11 43 28.12	191 41 01.45	Dry Ridge.
			125 27 13.87	305 21 59.23	Tanner.
Dry Ridge	38 40 39.104	84 34 40.393	118 01 02.71	297 45 16.74	Stow.
			169 51 37.69	349 48 50.68	Tanner.
Tanner	39 00 01.058	84 39 06.701	61 14 23.14	241 01 21.18	Stow.
			97 15 15.73	276 56 48.99	Reizin.
Indiana.					
Stow	38 51 05.066	84 59 51.239	82 43 20.96	262 35 59.08	Culbertson.
			150 29 33.03	330 24 10.43	Reizin.
Reizin	39 02 51.861	85 08 24.409	10 53 43.71	190 51 43.42	Culbertson.
			73 48 24.32	253 42 59.55	Correct.
Culbertson	38 49 54.097	85 11 35.794	96 08 34.07	276 01 32.53	Mud Lick.
			159 02 41.82	338 59 18.05	Correct.
Correct	39 00 54.704	85 17 00.121	54 56 42.53	234 45 34.94	Stout.
			117 00 12.82	296 51 54.82	Green.
Glasgow	39 06 16.575	85 17 49.909	294 51 39.47	114 57 35.93	Reizin.
			353 07 07.87	173 07 39.24	Correct.
Holton South Base	39 01 48.934	85 22 03.521	175 53 48.57	355 53 38.25	Holton North Base.
			282 52 43.40	102 55 54.53	Correct.
Holton North Base	39 04 46.850	85 22 19.895	246 52 52.33	66 55 42.58	Glasgow.
			312 55 26.20	132 58 47.65	Correct.
Mud Lick	38 50 50.134	85 22 47.962	92 09 03.91	272 01 35.73	Stout.
			204 10 09.97	24 13 48.55	Correct.
Green	39 06 07.790	85 30 10.445	13 20 11.06	193 17 19.97	Stout.
			46 50 25.48	226 45 05.80	Tripp.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Indiana—Continued.	° ′ ″	° ″	° ′ ″	° ′ ″	
Stout	38 51 10·513	85 34 42·438	88 32 28·85	268 15 15·94	Miller.
			160 44 13·41	340 41 45·48	Tripp.
Tripp	38 59 56·169	85 38 37·870	63 07 37·12	242 52 50·48	Miller.
			110 43 10·05	290 21 29·32	Weed Patch.
Miller	38 50 34·494	86 02 09·152	120 23 18·79	300 15 03·76	Fountain.
			156 27 14·97	336 20 24·67	Weed Patch.
Weed Patch	39 09 58·660	86 13 01·060	7 33 22·01	187 31 55·99	Fountain.
			79 04 15·71	258 49 34·37	Leonard.
Fountain	38 56 34·850	86 15 17·585	95 04 02·79	274 50 34·42	Beard.
			121 08 57·84	300 55 44·58	Leonard.
Rariden	38 45 25·830	86 30 48·203	159 51 51·15	339 48 08·31	Beard.
			227 19 36·26	47 29 20·02	Fountain.
Leonard	39 06 26·258	86 36 17·402	2 17 59·90	182 17 43·56	Beard.
			79 51 20·76	259 43 24·18	Calvary.
Beard	38 58 01·896	86 36 43·349	61 48 27·96	241 38 29·53	Osborn.
			125 02 16·26	304 54 36·73	Calvary.
Calvary	39 04 40·170	86 48 53·187	73 43 23·27	253 25 34·70	Sisson.
			98 12 02·67	277 57 38·99	Wright.
Osborn	38 51 21·495	86 52 36·075	109 39 04·33	289 23 38·32	Sisson.
			192 16 18·34	12 18 38·51	Calvary.
Wright	39 07 11·686	87 11 42·672	25 16 34·04	205 13 07·66	Sisson.
			76 30 54·75	256 16 55·84	Merom College.
Sisson	38 58 09·893	87 17 10·296	17 40 34·21	197 37 22·87	Summit..
			110 28 39·33	290 18 08·00	Merom College.
Summit	38 45 40·588	87 22 15·227	89 44 24·17	269 20 58·11	Claremont.
			121 38 08·58	301 25 22·28	Honey Creek.
Merom College	39 03 00·767	87 33 53·271	332 16 03·36	152 23 21·76	Summit.
			42 03 01·95	221 57 32·42	Honey Creek.
Illinois.					
Honey Creek	38 55 26·833	87 42 37·036	53 14 32·76	233 03 50·48	Claremont.
			120 48 25·05	300 36 53·02	Hunt City.
Belle Air	39 10 34·220	87 52 08·901	1 28 40·91	181 28 27·53	Oblong.
			46 00 48·72	225 55 15·64	Hunt City.
Oblong	38 59 52·455	87 52 30·121	21 18 01·03	201 13 30·50	Claremont.
			121 45 21·47	301 40 02·39	Hunt City.
Claremont	38 45 26·615	87 59 41·138	94 40 39·52	274 32 29·37	Denver.
			141 35 28·41	321 29 06·20	Newton.
Hunt City	39 03 56·647	88 00 56·795	356 56 42·36	176 57 29·88	Claremont.
			39 17 17·50	219 11 41·62	Newton.
Olney East Base	38 51 42·156	88 01 35·362	88 32 34·92	268 29 43·46	Olney West Base.
			149 33 26·74	329 32 18·71	Buffalo Mound.
Olney Check Base	38 48 18·597	88 01 57·885	135 17 55·12	315 15 17·89	Olney West Base.
			184 56 40·32	4 56 54·44	Olney East Base.
Buffalo Mound	38 54 06·250	88 03 23·742	341 27 17·15	161 29 36·72	Claremont.
			40 45 26·09	220 43 42·59	Olney West Base.
Olney Middle Base	38 51 39·412	88 03 52·125	88 31 12·11	268 29 46·46	Olney West Base.
			188 35 22·14	8 35 39·96	Buffalo Mound.
Onley West Base	38 51 36·633	88 06 08·628	320 38 04·66	140 42 07·51	Claremont.
			44 00 31·05	223 56 23·24	Denver.
Newton	38 55 26·655	88 09 50·566	13 51 05·56	193 49 16·79	Denver.
			93 35 18·63	273 25 12·78	Lucas.
Onion Hill	38 48 55·594	88 10 27·562	292 23 09·21	112 29 54·14	Claremont.
			33 47 57·93	213 46 32·46	Denver.
Denver	38 46 16·033	88 12 43·981	94 31 43·23	274 13 36·74	Holtzhausen.
			134 03 03·64	313 54 47·58	Lucas.
Island Creek	39 06 08·800	88 20 06·433	278 17 20·91	98 29 25·71	Hunt City.
			323 08 23·00	143 14 50·69	Newton.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Illinois—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Lucas	38 56 12·775	88 25 54·718	56 20 32·02	236 10 39·79	Holtzhausen.
			116 12 06·14	295 59 10·95	Mound.
Holtzhauser	38 47 59·966	88 41 38·452	63 16 58·05	243 08 09·73	Hartlin.
			115 11 11·32	294 55 52·26	Sturgess.
Mound	39 04 03·513	88 46 26·453	346 50 01·78	166 53 02·77	Holtzhausen.
			65 05 15·61	244 52 55·17	Sturgess.
Hartlin	38 42 26·249	88 55 42·451	73 42 18·52	253 26 51·86	Bording.
			150 52 19·12	330 45 50·16	Sturgess.
Sturgess	38 56 55·207	89 06 02·820	29 12 48·33	209 03 47·79	Bording.
			77 32 55·05	257 21 13·95	Hoile.
Bording	38 36 43·397	89 20 25·827	53 25 05·77	233 21 02·96	Geoffrey.
			111 03 15·54	290 49 19·14	Parkinson.
Hoile	38 53 41·157	89 24 38·758	348 57 55·44	169 00 33·77	Bording.
			54 08 28·34	233 57 07·88	Parkinson.
Geoffrey	38 32 56·277	89 26 55·188	78 31 10·74	258 14 08·91	Turkey Hill.
			104 19 30·78	284 07 55·34	Berger.
Parkinson	38 43 24·982	89 42 44·492	310 05 36·41	130 15 29·13	Geoffrey.
			17 44 51·67	197 43 08·02	Berger.
Berger	38 36 38·259	89 45 30·381	40 19 59·52	220 14 31·88	Turkey Hill.
			82 41 46·99	262 30 06·81	Clarks Mound.
Turkey Hill	38 28 31·075	89 54 16·203	96 29 36·40	276 18 37·75	Dreyer.
			128 32 54·41	308 26 42·80	Clarks Mound.
Sugar Loaf Mound	38 42 03·397	90 00 27·740	294 43 18·80	114 52 39·33	Berger.
			21 53 58·58	201 51 38·04	Clarks Mound.
American Bottom Upper Base	38 39 48·241	90 00 57·434	26 44 35·69	206 42 33·75	Clarks Mound.
			73 51 10·81	253 41 19·72	Insane Asylum.
American Bottom Lower Base	38 36 14·063	90 03 02·785	89 53 40·73	269 45 08·24	Insane Asylum.
			204 38 53·62	24 49 11·88	American Bottom Upper Base.
Clarks Mound	38 34 43·834	90 04 12·804	52 25 32·02	232 20 44·34	Dreyer.
			98 34 30·72	278 26 42·04	Insane Asylum.
Dreyer	38 30 04·410	90 11 54·524	92 12 11·72	272 07 28·24	Kleinschmidt.
			148 16 51·87	328 13 51·35	Insane Asylum.
Missouri.					
Insane Asylum	38 36 12·077	90 16 44·179	20 11 14·00	200 09 30·73	Kleinschmidt.
			126 24 32·26	306 20 05·53	Morgan.
Minoma	38 41 55·729	90 16 44·814	306 08 50·74	126 16 40·30	Clarks Mound.
			359 55 00·77	179 55 01·17	Insane Asylum.
Kleinschmidt	38 30 17·930	90 19 29·866	76 03 52·92	255 56 05·65	Patterson.
			161 09 52·79	341 07 09·69	Morgan.
Morgan	38 40 18·856	90 23 51·364	27 13 39·25	207 08 34·15	Patterson.
			76 33 43·02	256 20 24·86	Tavern Rock.
Patterson	38 27 50·770	90 32 00·737	70 10 15·61	250 02 47·99	Lynch.
			129 19 39·26	309 11 27·78	Tavern Rock.
Kessler	38 36 32·115	90 34 06·101	244 45 38·65	64 52 02·51	Morgan.
			349 17 35·79	169 18 53·89	Patterson.
Lynch	38 24 25·836	90 44 00·810	102 08 21·55	281 56 04·58	Peters.
			137 27 31·65	317 19 38·92	Dieckhaus.
Tavern Rock	38 36 17·242	90 45 09·645	355 38 45·50	175 39 28·36	Lynch.
			83 28 52·52	263 21 41·71	Dieckhaus.
Halleck	38 28 05·783	90 55 25·112	224 28 30·16	44 34 53·61	Tavern Rock.
			292 10 03·72	112 17 09·13	Lynch.
Dieckhaus	38 35 14·737	90 56 40·238	36 40 49·77	216 36 24·35	Peters.
			92 32 07·60	272 19 09·16	Berger.
Peters	38 27 44·685	91 03 46·370	81 28 22·32	261 20 39·75	Jacobs.
			127 21 34·75	307 13 02·83	Berger.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Missouri—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Enoch Knob	38 34 41·903	91 08 10·260	266 28 16·56	86 35 26·89	Dieckhaus.
			333 33 12·08	153 35 56·43	Peters.
Jacobs	38 26 16·301	91 16 10·250	100 10 06·56	280 03 57·91	Winter.
			173 58 54·95	353 58 06·43	Berger.
Berger	38 35 56·255	91 17 28·157	39 12 03·05	219 06 42·28	Winter.
			87 12 40·45	267 06 03·73	Gasconade.
Winter	38 27 39·496	91 26 03·106	84 33 15·09	264 27 10·70	Geyer.
			138 57 33·28	318 52 09·94	Turnpike Bluff.
Gasconade	38 35 31·461	91 28 04·104	348 36 09·08	168 37 24·45	Winter.
			89 15 21·32	269 11 12·99	Turnpike Bluff.
Turnpike Bluff	38 35 27·215	91 34 42·221	5 51 34·14	185 50 52·53	Geyer.
			80 49 56·02	260 42 26·99	Bradford.
Geyer	38 26 55·159	91 35 49·041	54 42 25·43	234 34 54·15	Pilot Knob.
			129 21 33·32	309 14 46·59	Bradford.
Bradford	38 33 55·356	91 46 42·300	4 00 13·52	183 59 27·88	Pilot Knob.
			39 02 58·71	218 58 53·73	McDaniel.
Pilot Knob	38 20 09·382	91 47 55·696	93 22 33·78	273 11 30·82	Kennedy.
			150 29 13·01	330 25 54·23	McDaniel.
McDaniel	38 27 33·820	91 53 15·731	56 08 45·72	236 01 00·67	Kennedy.
			125 04 42·15	304 55 06·55	Cedar.
Kennedy	38 20 57·677	92 05 44·353	96 00 30·89	275 48 59·45	Belshe.
			171 20 43·06	351 18 53·92	Cedar.
Cedar	38 36 02·051	92 08 39·767	42 17 13·19	222 07 29·01	Belshe.
			71 26 30·48	251 16 02·27	Moreau.
Medlock	38 38 11·415	92 20 13·606	31 53 45·02	211 50 29·26	Moreau.
			86 42 25·31	266 34 32·71	Christian.
Belshe	38 22 28·524	92 24 18·445	129 45 53·08	309 39 14·36	High Point.
			174 19 51·18	354 19 08·23	Moreau.
Moreau	38 31 35·065	92 25 27·507	74 13 19·04	254 07 22·66	High Point.
			136 18 29·50	316 03 53·20	Christian.
Christian	38 37 36·567	92 32 50·601	57 13 43·12	236 59 22·48	Hughes.
			100 53 00·42	280 41 10·70	Hubbard.
High Point	38 29 27·562	92 34 59·885	67 27 02·09	247 19 56·27	Hunter.
			191 43 00·40	11 44 20·98	Christian.
Cole	38 38 04·939	92 43 39·672	273 07 59·20	93 14 44·41	Christian.
			321 41 13·83	141 46 37·85	High Point.
Hunter (Versailles South Base)	38 25 43·380	92 46 24·515	91 29 51·67	271 23 58·80	Hughes.
			221 48 23·17	41 56 50·15	Christian.
Versailles North Base	38 29 32·961	92 48 23·465	270 25 13·01	90 33 33·16	High Point.
			337 49 24·80	157 50 38·78	Hunter.
Hubbard	38 40 26·316	92 51 46·934	55 37 55·29	235 25 38·83	Schnackenberg.
			98 47 06·92	278 34 12·02	Heard.
Hughes	38 25 54·674	92 55 52·224	107 49 18·74	287 39 36·81	Schnackenberg.
			192 26 25·00	12 28 57·87	Hubbard.
Schnackenberg	38 29 50·007	93 11 27·754	130 42 13·42	310 33 09·81	Kendrick.
			176 38 45·29	356 38 08·67	Heard.
Heard	38 42 54·579	93 12 26·440	72 51 22·63	252 42 54·40	Kendrick.
			102 48 44·02	282 35 47·47	Knob Noster.
Kendrick	38 39 37·133	93 25 59·501	52 15 13·02	232 10 00·46	High Point Tebo.
			141 13 12·61	321 08 45·09	Knob Noster.
Knob Noster	38 46 33·644	93 33 07·197	4 33 00·19	184 32 14·50	High Point Tebo.
			83 15 43·03	263 08 43·91	Normal.
High Point Tebo	38 34 32·466	93 34 20·304	86 52 18·34	266 45 25·43	Caldwell.
			144 41 23·15	324 35 10·62	Normal.
Normal	38 45 31·189	93 44 16·544	90 21 04·23	270 08 35·08	Baker.
			121 41 35·63	301 29 33·14	Chapel Hill.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Missouri—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Caldwell	38 34 03.529	93 45 22.550	128 03 41.97	307 51 55.61	Baker.
			184 17 53.67	4 18 34.91	Normal.
Chapel Hill	38 54 45.433	94 03 28.672	3 37 28.68	183 37 00.77	Baker.
			62 04 25.19	241 57 19.34	Thornton.
Baker	38 45 35.231	94 04 13.184	58 35 03.62	238 26 05.10	Fulton.
			118 27 34.79	298 20 57.54	Thornton.
Hutton Mound	38 32 49.578	94 10 50.214	134 04 18.05	313 59 28.46	Fulton.
			202 05 39.02	22 09 47.01	Baker.
Thornton	38 50 03.565	94 14 47.201	14 39 02.05	194 36 39.85	Fulton.
			114 39 35.27	294 34 01.20	Bowler.
Fulton	38 38 41.795	94 18 34.438	131 54 12.20	311 44 49.50	Berry.
			164 42 35.88	344 39 24.78	Bowler.
Bowler	38 53 14.285	94 23 39.643	62 31 46.84	242 25 34.13	Berry.
			115 20 19.06	295 09 53.43	Marty.
Berry	38 49 12.209	94 33 33.766	50 43 26.42	230 38 42.71	Haskin.
			152 46 49.40	332 42 37.35	Marty.
Kansas.					
Marty	38 59 21.002	94 40 15.109	49 29 05.24	229 20 40.04	Thomas.
			101 38 19.45	281 25 49.49	Eckman.
Haskin	38 44 21.827	94 41 06.741	121 33 30.22	301 25 38.73	Thomas.
			182 33 57.90	2 34 30.30	Marty.
Thomas	38 50 22.707	94 53 39.368	62 16 14.18	242 09 58.43	Bébé Mound.
			157 29 03.02	337 24 59.76	Eckman.
Eckman	39 02 30.678	95 00 06.402	9 41 05.23	189 38 51.73	Bébé Mound.
			80 59 12.83	260 44 19.15	Kanwaka.
Bébé Mound	38 46 15.524	95 03 38.966	92 41 28.42	272 27 25.90	Simmons.
			130 17 47.20	310 05 09.56	Kanwaka.
Kanwaka	38 59 32.552	95 23 45.945	8 12 52.01	188 11 25.21	Simmons.
			88 08 59.72	267 55 12.40	Elevation.
Simmons	38 47 02.869	95 26 04.206	92 42 09.84	272 28 57.15	Mabon.
			127 56 31.96	307 44 13.29	Elevation.
Elevation	38 58 57.340	95 45 40.928	67 33 07.84	247 19 34.47	Clark.
			104 18 12.29	284 06 25.06	Adams.
Mabon	38 47 47.712	95 47 09.534	104 55 05.99	284 42 29.81	Clark.
			185 53 48.06	5 54 43.69	Elevation.
Powell	38 55 27.858	95 55 41.587	245 52 50.60	65 59 08.23	Elevation.
			318 55 44.23	139 01 05.51	Mabon.
Adams	39 02 39.221	96 04 24.399	11 46 12.39	191 44 24.82	Clark.
			99 13 16.35	279 00 33.84	Zean Dale.
Clark	38 51 57.186	96 07 15.501	90 30 43.93	270 14 01.62	Reinhard.
			134 27 50.62	314 16 57.19	Zean Dale.
Meyer	38 55 37.881	96 18 16.014	236 56 17.99	57 05 01.18	Adams.
			293 05 29.24	113 12 23.99	Clark.
Zean Dale	39 05 10.571	96 24 34.343	29 05 00.58	208 59 09.63	Reinhard.
			113 52 39.11	293 41 11.71	Erricssen.
Reinhard	38 52 05.316	96 33 52.758	121 41 48.63	301 32 59.69	Robbins.
			160 23 38.07	340 18 03.92	Erricssen.
Humboldt	39 01 20.997	96 36 05.685	249 59 02.22	70 07 33.41	Zean Dale.
			340 24 34.28	160 27 13.26	Reinhard.
Erricssen	39 11 24.337	96 42 43.391	17 51 33.17	197 48 16.95	Robbins.
			74 52 13.39	254 39 49.41	Wilmer.
White City	38 48 08.745	96 43 45.048	163 06 37.59	343 04 00.90	Robbins.
			242 53 50.07	63 00 01.49	Reinhard.
Robbins	38 58 50.274	96 47 54.616	59 00 34.65	238 52 42.32	Taylor.
			126 47 32.23	306 38 26.00	Wilmer.
Taylor	38 52 56.720	97 00 26.258	79 26 55.55	259 07 56.96	Iron Mound.
			126 23 43.08	306 09 17.50	Vine Creek.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Kansas—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Wilmer	39 07 14·517	97 02 21·640	353 59 52·76	174 01 05·37	Taylor.
			86 02 24·79	265 49 09·78	Vine Creek.
Frey	39 01 25·452	97 10 23·358	227 02 55·58	47 07 59·21	Wilmer.
			317 26 32·44	137 32 47·83	Taylor.
Vine Creek	39 06 04·648	97 23 21·910	49 00 09·07	228 51 52·05	North Pole Mound.
			84 58 09·63	264 41 32·11	Thompson.
Iron Mound	38 48 28·227	97 30 41·555	152 17 57·31	332 14 17·82	North Pole Mound.
			197 57 49·71	18 02 26·12	Vine Creek.
Salina East Base	38 52 23·402	97 31 57·757	345 46 21·70	165 47 09·49	Iron Mound.
			68 39 03·02	248 36 24·22	Salina West Base.
Salina West Base	38 51 05·968	97 36 10·842	177 28 58·35	357 28 45·55	North Pole Mound.
			301 27 16·24	121 30 42·71	Iron Mound.
North Pole Mound	38 57 08·164	97 36 31·232	72 42 23·68	252 25 47·13	Heath.
			124 33 23·04	304 25 03·98	Thompson.
Thompson	39 04 13·094	97 49 44·054	37 21 29·88	217 13 10·54	Heath.
			95 41 39·27	275 31 26·60	Lincoln.
Heath	38 50 38·748	98 02 58·239	93 24 29·22	273 07 59·75	Wilson.
			123 46 09·91	303 36 28·13	Golden Belt.
Lincoln	39 05 27·490	98 05 55·902	351 06 50·77	171 03 42·50	Heath.
			55 13 52·24	235 06 00·80	Golden Belt.
Golden Belt	38 58 41·184	98 18 24·467	51 02 59·32	230 56 10·32	Wilson.
			143 21 20·12	323 12 26·56	Meades Ranch.
Wilson	38 51 49·230	98 29 15·488	92 27 01·80	272 18 49·22	Bunker Hill.
			173 19 26·63	353 17 23·81	Meades Ranch.
Meades Ranch	39 13 25·006	98 32 30·469	19 57 42·79	199 51 31·12	Bunker Hill.
			75 28 16·52	255 17 19·53	Waldo.
Bunker Hill	38 52 14·760	98 42 20·450	71 05 23·30	250 59 08·06	Allen.
			161 42 57·10	341 38 14·03	Waldo.
Waldo	39 09 53·973	98 49 50·086	5 26 34·01	185 25 00·51	Allen.
			48 58 34·81	228 48 24·78	Blue Hill.
Allen	38 49 34·017	98 52 18·677	34 29 47·06	214 24 47·89	Fairmount.
			131 20 00·31	311 11 25·83	Blue Hill.
Fairmount	38 40 28·497	99 00 16·632	68 44 22·70	248 34 27·46	La Crosse.
			138 59 40·65	318 49 39·12	Hays.
Blue Hill	38 58 55·645	99 05 57·893	346 24 50·71	166 28 24·68	Fairmount.
			63 07 35·71	243 01 06·70	Hays.
La Crosse	38 35 36·279	99 16 10·022	179 44 23·20	359 44 19·00	Hays.
Hays	38 54 50·180	99 16 16·730			
Smoky Hill	38 43 33·435	99 32 53·638	228 57 53·51	49 08 18·45	Hays.
			301 05 34·09	121 19 01·05	La Crosse.
Trego	38 53 53·900	99 38 15·858	266 45 34·78	86 59 23·25	Hays.
			337 51 30·53	157 54 52·49	Smoky Hill.
Skaggs	38 39 26·489	99 45 14·891	200 40 41·95	20 45 04·39	Trego.
			246 54 26·09	67 02 09·47	Smoky Hill.
Big Creek	38 55 37·766	99 54 22·409	277 44 48·78	97 54 55·91	Trego
			336 08 45·16	156 14 28·18	Skaggs.
Schmidt	38 41 44·859	100 03 17·123	206 37 27·99	26 43 03·13	Big Creek
			279 10 09·29	99 21 25·61	Skaggs.
Canyon	38 39 23·732	100 26 14·658	171 53 27·90	351 52 01·56	Indian Creek.
			262 26 05·63	82 40 26·48	Schmidt.
Indian Creek	38 52 00·456	100 28 32·565	262 05 49·65	82 27 17·00	Big Creek.
			297 17 41·80	117 33 31·00	Schmidt.
Beaver	38 43 23·045	100 51 47·331	244 31 03·00	64 45 36·87	Indian Creek.
			281 08 00·77	101 23 58·86	Canyon.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back Azimuth.	To station.
Kansas—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Monument	38 53 54·848	100 53 05·527	275 32 44·11	95 48 08·74	Indian Creek.
			354 27 43·02	174 28 32·03	Beaver.
Gopher	38 59 25·849	101 09 29·828	293 12 38·39	113 22 57·09	Monument.
			319 06 59·32	139 18 05·91	Beaver.
Sheridan	38 51 31·970	101 21 16·785	229 18 23·26	49 25 47·44	Gopher.
			289 17 28·18	109 35 56·71	Beaver.
Teeters Hill	39 04 21·583	101 28 35·675	288 12 31·02	108 24 32·62	Gopher.
			335 57 42·20	156 02 18·20	Sheridan.
Wallace Bluffs	38 50 54·794	101 34 57·335	200 14 19·51	20 18 19·49	Teeters Hill.
			266 36 45·42	86 45 20·18	Sheridan.
Turtle	39 01 16·340	101 45 25·657	256 40 34·98	76 51 11·23	Teeters Hill.
			321 39 03·88	141 45 38·74	Wallace Bluffs.
Curlew	38 50 24·510	101 46 56·592	186 12 40·02	6 13 37·16	Turtle.
			266 51 20·35	86 58 51·47	Wallace Bluffs.
McLane	39 01 52·813	101 57 49·239	273 31 58·83	93 39 47·05	Turtle.
			323 25 10·06	143 32 00·22	Curlew.
Colorado.					
Arapahoe	38 45 59·937	102 05 43·784	201 13 25·26	21 18 23·25	McLane.
			253 12 19·14	73 24 05·50	Curlew.
Monotony	39 01 43·174	102 14 58·513	269 13 19·71	89 24 07·87	McLane.
			335 16 05·30	155 21 53·63	Arapahoe.
Cheyenne Wells	38 57 01·985	102 24 01·571	236 23 26·57	56 29 08·25	Monotony.
			307 32 47·67	127 44 16·42	Arapahoe.
First View	38 47 41·241	102 32 55·253	216 36 13·89	36 41 48·82	Cheyenne Wells.
			274 23 36·80	94 40 38·66	Arapahoe.
Landsman	38 56 50·877	102 35 14·970	268 43 51·91	88 50 55·22	Cheyenne Wells.
			348 44 53·13	168 46 20·81	First View.
Kit Carson	38 42 06·062	102 51 34·976	179 30 21·80	359 30 14·93	Eureka.
			248 59 03·08	69 10 43·91	First View.
Eureka	38 58 38·551	102 51 45·938	277 50 10·21	98 00 33·34	Landsman.
			306 32 31·61	126 44 21·42	First View.
Overland	39 02 18·796	103 10 15·517	284 10 33·60	104 22 12·00	Eureka.
			2 06 24·89	182 05 59·77	Aroya.
Aroya	38 48 08·456	103 10 55·494	234 51 27·04	55 03 28·76	Eureka.
			291 38 21·59	111 50 28·02	Kit Carson.
Hugo	39 04 31·579	103 30 48·863	277 45 13·03	97 58 10·15	Overland.
			316 25 24·03	136 37 54·05	Aroya.
Adobe	38 40 39·312	103 33 16·252	184 35 10·73	4 36 43·24	Hugo.
			246 43 36·42	66 57 35·45	Aroya.
Square Bluffs	38 51 06·826	103 49 43·527	227 38 54·67	47 50 48·18	Hugo.
			308 59 01·48	129 09 19·64	Adobe.
Cramers Gulch	38 35 34·608	103 55 54·260	197 16 21·57	17 20 13·48	Square Bluffs.
			253 55 08·16	74 09 16·05	Adobe.
Holt	39 02 19·481	103 58 17·246	263 59 15·28	84 16 33·92	Hugo.
			329 08 31·64	149 13 54·55	Square Bluffs.
Big Springs	38 45 04·960	104 15 09·598	253 00 34·85	73 16 31·13	Square Bluffs.
			302 05 53·08	122 17 55·01	Cramers Gulch.
Holcolm Hills	39 00 06·702	104 18 59·703	262 05 27·58	82 18 29·82	Holt.
			348 41 55·81	168 44 20·23	Big Springs.
El Paso East Base	38 57 20·837	104 27 41·835	160 58 36·22	340 56 41·23	Divide.
			247 48 35·66	67 54 04·10	Holcolm Hills.
Divide	39 04 13·822	104 30 44·505	294 08 41·03	114 16 04·92	Holcolm Hills.
			327 28 09·09	147 37 56·32	Big Springs.
Plateau	38 23 30·892	104 33 17·155	139 36 05·445	319 17 47·008	Pikes Peak.
			213 19 21·822	33 30 31·910	Big Springs.
El Paso West Base	38 58 41·701	104 35 19·176	212 48 12·99	32 51 05·94	Divide.
			282 43 15·63	102 45 03·24	El Paso East Base.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Continued.

Station.	Latitude.	Longitude.	Azimuth.	Back Azimuth.	To station.
Colorado—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Corral Bluffs	38 52 10·187	104 35 34·202	181 42 57·44	1 43 06·88	El Paso West Base.
			229 52 15·44	49 57 12·15	El Paso East Base.
Pikes Peak	38 50 24·821	105 02 37·173	240 47 58·277	61 08 00·807	Divide.
			277 55 11·726	98 24 55·882	Big Springs.
Bison	39 14 17·078	105 29 50·072	282 00 54·549	102 38 13·294	Divide.
			318 12 52·454	138 30 00·947	Pikes Peak.
Mount Ouray	38 25 20·742	106 13 27·164	214 39 22·412	35 06 43·423	Bison.
			245 20 57·667	66 05 11·041	Pikes Peak.
Mount Elbert	39 07 02·980	106 26 41·258	260 24 56·171	81 00 51·146	Bison.
			345 58 40·578	166 06 57·845	Mount Ouray.
Treasury Mountain	39 00 50·531	107 05 54·569	258 19 07·309	78 43 50·404	Mount Elbert.
			310 32 34·915	131 05 23·638	Mount Ouray.
Uncompahgre	38 04 17·000	107 27 41·604	196 43 04·098	16 56 38·538	Treasury Mountain.
			249 39 56·658	70 35 54·265	Mount Ouray.
Tavaputs	39 32 22·578	109 00 18·920	288 55 13·333	110 07 39·219	Treasury Mountain.
			9 53 09·781	189 44 46·392	Mount Waas.
Utah.					
Mount Waas	38 32 20·100	109 13 38·107	253 25 18·358	74 45 18·285	Treasury Mountain.
			288 01 27·850	109 07 08·151	Uncompahgre.
Patmos Head	39 30 07·236	110 18 57·650	267 27 44·066	88 17 46·947	Tavaputs.
			318 14 47·969	138 55 55·837	Mount Waas.
Mount Ellen	38 07 15·815	110 48 50·421	195 36 04·462	15 54 48·182	Patmos Head.
			251 01 27·773	72 00 30·654	Mount Waas.
Wasatch	39 06 53·072	111 27 11·612	245 58 16·210	66 41 29·774	Patmos Head.
			333 01 10·894	153 25 07·186	Mount Ellen.
Mount Nebo	39 48 37·831	111 45 56·571	284 55 42·684	105 51 13·412	Patmos Head.
			340 42 17·269	160 54 12·279	Wasatch.
Ogden Peak	41 11 59·483	111 52 52·644	356 19 44·249	176 24 14·515	Mount Nebo.
			37 36 35·819	217 07 23·873	Deseret.
Waddoup	40 54 24·723	111 53 10·088	102 33 19·834	282 20 23·402	Antelope.
			180 42 56·584	0 43 08·041	Ogden Peak.
Salt Lake Southeast Base	41 02 17·285	112 01 04·094	63 05 26·267	242 57 39·788	Antelope.
			135 44 39·223	315 40 59·151	Salt Lake N. W. Base.
Salt Lake Northwest Base	41 06 37·160	112 06 39·041	242 37 46·176	62 46 50·027	Ogden Peak.
			28 06 09·746	208 02 02·833	Antelope.
Antelope	40 57 43·107	112 12 55·126	226 37 36·019	46 50 46·202	Ogden Peak.
			31 59 13·590	211 43 10·205	Deseret.
Tushar	38 25 09·052	112 24 42·680	199 41 13·505	20 05 41·112	Mount Nebo.
			226 52 40·655	47 28 41·626	Wasatch.
Promontory	41 17 52·429	112 25 08·824	283 24 03·067	103 45 19·656	Ogden Peak.
			335 17 23·212	155 25 25·818	Antelope.
Deseret	40 27 34·047	112 37 32·152	314 14 14·716	134 47 30·152	Mount Nebo.
			57 57 44·533	237 07 42·399	Ibepah.
Ibepah	39 49 41·249	113 5[illegible]·545	269 55 05·588	91 17 50·052	Mount Nebo.
			319 43 05·669	140 40 09·748	Tushar
Nevada.					
Pioche	37 59 09·695	114 03 04·536	168 26 37·464	348 16 5[illegible]·592	Wheeler Peak.
			250 58 58·550	71 59 48·697	Tushar.
Pilot Peak	41 01 16·035	114 04 35·826	296 29 40·354	117 26 35·633	Deseret.
			354 11 03·805	174 17 11·676	Ibepah.
Wheeler Peak	38 59 08·671	114 18 47·535	199 49 35·293	20 04 36·128	Ibepah.
			290 13 22·377	111 24 42·592	Tushar.
White Pine	38 19 09·571	115 30 04·461	234 03 13·165	54 47 44·619	Wheeler Peak.
			285 46 50·743	106 40 35·519	Pioche.
Diamond Peak	39 35 05·765	115 49 04·554	296 39 07·565	117 36 17·695	Wheeler Peak.
			348 50 38·479	169 02 35·267	White Pine.

G. RESULTING GEOGRAPHIC POSITIONS, ETC.—Completed.

Station.	Latitude.	Longitude.	Azimuth.	Back azimuth.	To station.
Nevada—Continued.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
Mount Callahan	39 42 33·896	116 57 00·210	277 43 59·104	98 27 19·661	Diamond Peak.
			19 45 19·031	199 30 02·413	Toiyabe Dome.
Toiyabe Dome	38 49 57·717	117 21 08·241	237 18 00·056	58 16 12·047	Diamond Peak.
			288 52 43·547	110 01 59·024	White Pine.
Lone Mountain	38 01 27·672	117 29 37·303	118 30 47·691	297 42 34·067	Mount Grant.
			187 47 29·492	7 52 45·901	Toiyabe Dome.
Carson Sink	39 34 59·172	118 14 04·648	262 20 31·317	83 09 41·995	Mount Callahan.
			317 16 03·312	137 49 31·301	Toiyabe Dome.
Mount Grant	38 34 13·398	118 47 26·199	202 59 36·386	23 20 38·141	Carson Sink.
			256 27 00·812	77 20 58·512	Toiyabe Dome.
Mount Como	39 01 17·044	119 28 23·190	239 20 08·029	60 07 12·220	Carson Sink.
			309 57 47·380	130 23 26·825	Mount Grant.
Pah-Rah	39 47 40·397	119 28 24·214	359 59 00·786	179 59 01·436	Mount Como.
			62 36 06·453	242 02 01·661	Mount Lola.
California.					
Mount Conness	37 58 01·568	119 19 13·860	142 39 29·965	322 14 12·905	Round Top.
			214 32 21·756	34 52 03·289	Mount Grant.
Round Top	38 39 49·318	120 00 00·709	228 53 10·154	49 13 00·255	Mount Como.
			275 14 16·026	95 59 33·791	Mount Grant.
Mount Lola	39 25 59·077	120 21 51·126	300 25 34·769	120 59 23·498	Mount Como.
			339 38 03·003	159 51 48·555	Round Top.
Mocho	37 28 38·756	121 33 18·412	118 41 29·649	298 03 18·514	Mount Tamalpais.
			144 57 42·656	324 44 34·421	Mount Diablo.
Yolo Southeast Base	38 31 41·254	121 47 58·085	55 49 16·447	235 38 39·989	Vaca.
			114 01 57·873	293 47 22·148	Monticello.
Yolo Northwest Base	38 40 43·877	121 51 28·111	343 05 10·607	163 07 21·648	Yolo Southeast Base.
			86 47 32·345	266 35 06·415	Monticello.
Mount Diablo	37 52 54·554	121 54 47·958	217 34 54·104	38 32 58·193	Mount Lola.
			242 00 26·990	63 11 33·335	Round Top.
Vaca	38 22 32·887	122 05 01·560	344 42 03·229	164 48 22·090	Mount Diablo.
			124 25 51·469	304 05 20·881	Mount Helena.
Monticello	38 39 49·728	122 11 21·880	343 53 27·358	163 57 24·217	Vaca.
			91 04 30·326	270 47 53·483	Mount Helena.
Mount Tamalpais	37 55 26·605	122 35 44·834	177 46 56·984	357 45 34·848	Mount Helena.
			274 15 22·127	94 40 31·460	Mount Diablo.
Mount Helena	38 40 10·180	122 37 57·365	245 56 20·714	67 22 06·093	Mount Lola.
			324 01 37·516	144 28 21·564	Mount Diablo.
Snow Mountain West	39 22 37·556	122 45 28·122	352 06 04·73	172 10 48·55	Mount Helena.
			18 03 06·70	197 49 29·18	Ross Mountain.
Mount Sanhedrin	39 30 57·809	123 05 43·017	297 51 50·58	118 04 42·47	Snow Mountain West.
			34 02 43·07	213 46 30·21	Cold Spring.
Ross Mountain	38 30 19·701	123 07 08·774	246 36 11·868	66 54 24·242	Mount Helena.
			324 27 25·046	144 46 50·491	Mount Tamalpais
Paxton	39 08 08·322	123 18 42·764	55 25 25·22	235 17 27·88	Cold Spring.
			155 25 58·00	335 20 54·51	Two Rock.
Two Rock	39 21 42·653	123 26 42·451	10 02 46·19	189 59 50·81	Cold Spring.
			84 34 47·96	264 24 21·03	Great Caspar.
Cold Spring	39 01 20·503	123 31 19·984	238 56 49·43	59 25 48·70	Snow Mountain West.
			296 36 51·14	117 10 19·95	Mount Helena.
Fisher	39 03 58·856	123 35 11·270	251 58 04·18	72 08 27·62	Paxton.
			311 15 39·32	131 18 05·01	Cold Spring.
Great Caspar	39 20 28·639	123 43 11·178	249 57 35·51	70 21 23·36	Mount Sanhedrin.
			334 11 52·94	154 19 22·26	Cold Spring.

H. ARC MEASUREMENTS.

I. RELATION OF THE ARC OF THE PARALLEL (OF 1871–1898) TO OTHER AMERICAN ARCS.

Our account of the arc of the thirty-ninth parallel would still remain incomplete without some reference to its bearing upon other arcs measured or being measured in the United States, since by itself it is incapable of furnishing any results of the earth's figure and magnitude. To that end combinations with measures of like import are demanded, and which will set into clearer light some of the larger operations of the Survey.

In the first place, it should be remarked that last year has also seen the completion of the field work pertaining to the measurement of an oblique arc along our Atlantic coast and binding it to the Gulf coast. It stretches from Maine to Louisiana and, like the arc of the parallel, is incidental to the regular work of the Survey. In point of age, however, it reaches back to the time of the first Superintendent. The northeastern terminus is at Calais, Maine, opposite the Canadian boundary, in latitude $45° \ 11' \ 09''\cdot4$ and in longitude $67° \ 16' \ 57''\cdot9$ west of Greenwich, and its southwestern terminus is at New Orleans, Louisiana, in latitude $29° \ 57' \ 25''\cdot3$ and in longitude $90° \ 04' \ 24''\cdot4$ (station of 1858). The length of the geodetic line connecting these positions is 2 612·28 kilometres, or 1 623·2 statute miles.* The triangulation is supported by 6 base lines and the astronomic part consists of about 71 latitudes, 56 azimuths, and 17 telegraphic longitude determinations. It is intended to take up the final computation of this arc without delay and the publication of its results may therefore be expected at no distant date.

Two smaller arcs of the meridian were measured some years ago. A preliminary account of these will be found in Coast Survey Report for 1868, Appendix No. 9, and in Coast Survey Report for 1877, Appendix No. 6. The first is known as the Nantucket arc, which has an extension of $3° \ 22' \ 39''\cdot2$, or 375·22 kilometres (or 233·15 statute miles), and contains 7 astronomic latitudes; the second is known as the Pamlico-Chesapeake arc, which extends over $4° \ 31' \ 30''\cdot1$, or 502·34 kilometres (or 312·14 statute miles) and is supported by 14 astronomic latitudes. Each of these arcs, therefore, is longer than the Peruvian arc and astronomically better sustained, and both are capable of farther extension northward. The results given in the reports of 1868 and 1877 are now in need of revision before they can be finally utilized.

It is well known that the Survey is now actively engaged in prosecuting the measurement of what is designated "the central arc of the meridian," which runs along the meridian of 98° west of Greenwich and intersects the central arc of the parallel just west of the Salina Base Line. Its full extent within the limits of the United States between the Mexican boundary at the Rio Grande, Texas, and the northern

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* The line may be plotted on any projection by means of the geographic positions of its terminals and the following positions of two intermediate points in it, viz:

$$\begin{cases} \varphi = 35° \\ \lambda = 84 \ \ 08'\cdot2 \end{cases} \quad \text{and} \quad \begin{cases} \varphi = 40° \\ \lambda = 76 \ \ 59'\cdot6 \end{cases}$$

The azimuths of the geodetic line are $223° \ 22' \ 31''$ at New Orleans and $57° \ 30' \ 44''$ at Calais.

boundary at the British Possessions is 23° 06′; i. e. from Brownsville in latitude 25° 54′ to latitude 49° 00′. It is, however, capable of considerable extension, as it may be made to abut on the Pacific coast east of Acapulco, Mexico, in latitude 16° north, on the one hand, and on the other may be carried over the Lake Winnipeg region indefinitely northward into British Northwest Territory. The measurement of this arc was proposed in March, 1881, to Superintendent Patterson, who then approved of the meridian of 98°, but no action was taken until 1897; since that time the reconnaissance from the Rio Grande to latitude 39° has been made, while to the northward of that latitude the triangulation is completed well into the middle latitude of Nebraska. It will be noticed that the central arc of the parallel and that of the central meridian are complementary to each other and will furnish data of the curvature east and west and north and south for the determination of an oscillatory spheroid in this region.

The United States is also in possession of two other arcs, one of the meridian, the other of the parallel, which were measured by the United States Engineer Corps working under the special organization of the Survey of the Great Lakes. A full account has been published by Lieut. Col. C. B. Comstock under the title "Professional Papers, Corps of Engineers, United States Army, No. 24. Primary Triangulation United States Lake Survey," Washington, 1882. Neither of these arcs could be utilized in combination with other like measures by reason of an unknown correction attaching to the unit of length as used by the Lake Survey at the time of publication; and the subsequent suspension of that Survey left no occasion to remove the deficiency. Since that date the Coast and Geodetic Survey has been charged with measures of this character, which is also manifest by the United States joining the convention of October, 1886, as a member of the International Geodetic Association. The above measures may be regarded as an inheritance to be preserved and supplied with any needful data and extended in order to carry out the original idea which led to their conception.

The unit of length of the United States Lake Survey was the so-called Repsold metre or R_{1876}, for which standard General Comstock published, under date of February, 28, 1885, the result from comparisons made at the International Bureau of Weights and Measures, at Breteuil. The length of this metre has been discussed and its final relation to the Prototype Metre determined by the Coast and Geodetic Survey, as given in the report for 1889, Appendix No. 6, and is referred to in Part I of this paper in connection with the Olney Base Line. The result was $R_{1876} = 1$ metre Committee $+ 98{\cdot}2\mu \pm 0{\cdot}7\mu$ at 0° C. and for any other temperature, $t°$ Centigrade, the difference—

$$R_{1876} - C.\,M. = \underset{\pm 0{\cdot}49}{+\,84{\cdot}28\mu} - \underset{\pm\,42\;5}{1{\cdot}192\;5}\,(t - 11°{\cdot}66),$$

and the coefficient of expansion α of $R_{1876} = \underset{\pm\,25}{10{\cdot}606\mu}$. The $C.\,M.$ was found to be sensibly equal to the Prototype Metre; hence we get for the length of R_{1876} at the temperature 57°·92 F. (or at 14°·40 C.) the value 1 metre $+ \underset{\pm\,{\cdot}8}{250{\cdot}9}$ microns, which result was used for the conversion of the linear measures of the Lake Survey tables of pages 823 and 826 of the Professional Papers. We content ourselves here with transcrib-

ing the astronomic results without any change; such for instance as a correction for variation of pole. The corrected tabular results are as follows:

2. ARC OF THE MERIDIAN BETWEEN PARKERSBURG, ILLINOIS, AND ST. IGNACE, ONTARIO.

Stations.	Observed latitudes.	Intervals from Parkersburg to the several parallels.
	° ′ ″	*Metres.*
Parkersburg	38 34 53·20	0·0
West Base, Olney	38 51 41·23	31 052·9
Fairmount	40 01 36·70	160 490·2
Willowsprings	41 43 38·63	349 311·4
Minnesota Junction	43 28 31·82	543 449·1
Fort Howard	44 30 30·28	658 322·2
Ford River	45 41 05·34	789 271·9
Huron Mountains	46 52 53·07	921 739·3
Vulcan	47 26 44·58	984 873·0
St. Ignace	48 47 28·65	1 134 127·8

3. ARC OF THE PARALLEL OF 42° BETWEEN WILLOWSPRINGS, ILLINOIS, AND MANNSVILLE, NEW YORK.

Stations.	Observed longitudes referred to Detroit, Michigan.	Intervals from Willowsprings to the several meridians.
	° ′ ″	*Metres.*
Willowsprings	+ 4 48 03·15	
	(0 00 00·00)	0·0
Cedar Point	+ 17 01·84	
	(− 4 31 01·31)	374 218·4
Tonawanda	− 4 09 42·44	
	(− 8 57 45·59)	742 569·2
Mannsville	− 6 59 36·86	
	(−11 47 40·01)	977 491·0

The St. Ignace-Parkersburg meridian as it stood in 1882 obviously represents only *one-half* of what its ultimate length was to be. Its extension southward to the Gulf, where it joins the oblique arc, is thus plainly demanded. The Willowsprings-Mannsville arc fared better since that date, the Coast and Geodetic Survey having added at both ends triangulations of its own, which may now be utilized to a considerably larger extent, namely, from Cape Cod, Massachusetts, to Dubuque, Iowa. The only field work still needed is the telegraphic longitude determinations at these terminal places.

For brevity's sake we shall call the meridional arc "the Lake Superior arc," and that of the parallel "the Lake Erie arc." Scrutinizing the measures of the Lake Superior arc, we get for the whole of it the average value of 1° or $\frac{1\ 134\ 127{\cdot}8}{10{\cdot}209\ 85}$ metres $= 111\ 081{\cdot}7$ metres, and for the partial arc, omitting the first and last stations, $\frac{953\ 820{\cdot}1}{8{\cdot}584\ 26}$ metres $= 111\ 112{\cdot}6$ metres. For the respective mean latitude on the

$\begin{Bmatrix}\text{Clarke}\\ \text{Bessel}\end{Bmatrix}$ spheroid we have $\begin{Bmatrix}111\ 105{\cdot}0\\ 111\ 093{\cdot}9\end{Bmatrix}$ metres and $\begin{Bmatrix}111\ 094{\cdot}4\\ 111\ 083{\cdot}5\end{Bmatrix}$ metres.* From these figures we infer that, as far as the whole arc is concerned, the measures favor the smaller of the two spheroids, but when the terminal stations are lopped off, the remaining sub-arc leans toward the larger one, so that there appears little choice between the two representative spheroids. It is different with the Lake Erie arc. Here the measures all demand a larger spheroid even than that of Clarke's.

The meridional arc measured by Mason and Dixon between the Delaware Bay and the Chesapeake Bay in 1764 is now obsolete. It crosses the transcontinental triangulation close to the station Hartly. Its middle latitude is 39° 12′ and its length is but 1° 28′·75. For particulars see Phil. Trans. R. S. for 1768.

I. PRELIMINARY PARTIAL COMBINATION OF AMERICAN ARCS.

By combining the central arc of the parallel with the Lake Superior arc of the meridian, we can obtain at least an approximate value for an osculating spheroid answering to the compact part of the United States. It suffices here to use terminal stations only, and for reasons already stated to substitute a mean value for the first and second stations of the arc of parallel and a mean for the last and its preceding station of the Lake Superior arc.

For an arc of meridian, let A = length of arc as directly measured, φ and φ' its astronomically observed terminal latitudes, also, as usual, a the equatorial radius and b the polar semiaxis of the spheroid; also $e = (a - b)/b$, then we have†—

$$A = b\left\{1 - e + 3e\sin^2\frac{\varphi' + \varphi}{2}\right\}(\varphi' - \varphi)\sin 1'' \ldots\ldots\ldots\ldots (1)$$

For an arc of parallel, let C = length of arc as directly measured, D the astronomic difference of longitude (in seconds) of its terminal stations in latitude φ_1; then we have

$$C = b\cos\varphi_1\,(1 + e + e\sin^2\varphi_1)\,D\sin 1'' \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

From equations (1) and (2) the values of b and e can be deduced.

For the combination of two meridional arcs, we have the following simple expressions: Let $\sigma_1\ \sigma_2$ = the measured lengths of the arcs, $\varphi_1\ \varphi_2$ their astronomic amplitudes, and $\varphi_0\ \psi_0$ their mean latitudes; also put—

$$n = (a - b)/(a + b)\text{, then‡—}$$

$$n = \frac{1}{3}\cdot\frac{(\sigma_2\varphi_1)/(\sigma_1\varphi_2) - 1}{\cos 2\varphi_2 - \cos 2\psi_0}$$

$$\text{and } a(1 - n) = \frac{\sigma_2\,\varphi_1\cos 2\varphi_0 - \sigma_1\,\varphi_2\cos 2\psi_0}{\varphi_1\,\varphi_2(\cos 2\varphi_0 - \cos 2\psi_0)},$$

whence a and b follow.

*Clarke: $M^\circ = 111\ 132{\cdot}090 - 566{\cdot}078\cos 2\varphi + 1{\cdot}202\cos 4\varphi - 0{\cdot}002\ 4\cos 6\varphi + \ldots\ldots$
Bessel: $M^\circ = 111\ 120{\cdot}619 - 558{\cdot}080\cos 2\varphi + 1{\cdot}168\cos 4\varphi - 0{\cdot}002\ 2\cos 6\varphi + \ldots\ldots$

†Airy's Figure of the earth, Cyclopædia Metropolitana (about 1830); also Phil. Trans. 1826.

‡Brit. Ordn. Survey, London, 1858, Section X, p. 561.

For the case of the Lake Superior arc in combination with the United States Central arc of the parallel, we have the following data: $A = 1\ 059\ 500 - 15\ 526 = 1\ 043\ 974$ metres, $\varphi = 38^\circ\ 43'\ 17''\cdot 22$, $\varphi' = 48^\circ\ 07'\ 06''\cdot 62$ and $C = 4\ 182\ 227$ metres, $D = 173\ 807''\cdot 83$ and $\varphi_1 = 39^\circ$. Whence we deduce $a = 6\ 377\ 912$ and $b = 6\ 356\ 309$ metres.

For the case of the United States Central arc of the parallel and the Peruvian arc, we have the data $C\ D\ \varphi_1$ as above and for the South American arc* $A = 344\ 736\ 8$ metres, $\varphi = -3^\circ\ 04'\ 32''\cdot 0$ and $\varphi' = +0^\circ\ 02'\ 31''.4$. Whence we get $a = 6\ 378\ 027$ and $b = 6\ 356\ 819$ metres.

The results from the combination of the Nantucket and the Pamlico-Chesapeake arcs of meridian with the Peruvian arc are given in the Coast Survey report for 1877, p. 94,† viz: $a = 6\ 378\ 054$ and $b = 6\ 357\ 175$ metres. In this combination the subdivisions of the arcs in the United States were made use of.

For the case of the Lake Erie and the Peruvian arcs, we have the data: $C = 977\ 491$ metres, $D = 42\ 460''\cdot 0$, $\varphi_1 = 42^\circ$, and those for the southern arc as before; whence we find $a = 6\ 379\ 822$ and $b = 6\ 357\ 716$ metres.

For the case of the Lake Superior and the Peruvian arcs, with data as given above, we deduce: $a = 6\ 377\ 577$ and $b = 6\ 356\ 777$ metres.

In the following table the above results, besides some other useful data, are collected for ready comparison:

Comparative table of preliminary values from American measures for the earth's equatorial radius (a) and its polar semiaxis (b) with the values pertaining to representative spheroids as deduced by Clarke and Bessel.

Arcs and their combinations.	No.	Amplitudes.	No. of astronomic stations.	a In metres.	b In metres.	a–b	$\frac{a-b}{a}$
Bessel's spheroid of 1841	1	$\Sigma = 50^\circ\ 35'\cdot 4$	38 φ's	6 377 397	6 356 079	21 318	$\frac{1}{299.2}$
Clarke's spheroid of 1866	2	$\Sigma = 76\ \ 35\ \cdot 0$	40 φ's	6 378 206	6 356 584	21 622	$\frac{1}{295.0}$
American Central arc of parallel (39°) Lake Superior arc of meridian	3	$48^\circ\ 16'\cdot 8 \cos\varphi$ $9\ \ 23\ \cdot 8$	28 λ's 10 φ's	6 377 912	6 356 309	21 603	$\frac{1}{295.2}$
American Central arc of parallel (39°) Peruvian arc of meridian	4	$48\ \ 16\ \cdot 8 \cos\varphi$ $3\ \ 07\ \cdot 1$	28 λ's 2 φ's	6 378 027	6 356 819	21 208	$\frac{1}{300.7}$
Lake Erie arc of parallel (42°) Peruvian arc of meridian	5	$11\ \ 47\ \cdot 7 \cos\varphi$ $3\ \ 07\ \cdot 1$	4 λ's 2 φ's	6 379 822	6 357 716	22 106	$\frac{1}{288.6}$
Lake Superior arc of meridian Peruvian arc of meridian	6	$9\ \ 23\ \cdot 8$ $3\ \ 07\ \cdot 1$	10 φ's 2 φ's	6 377 577	6 356 577	21 000	$\frac{1}{303.7}$
The Nantucket and Pamlico-Chesapeake arcs of meridian Peruvian arc of meridian	7	$\Sigma = 11^\circ\ 01'\cdot 2$ $3\ \ 07\ \cdot 1$	7+14 φ's 2 φ's	6 378 054	6 357 175	20 879	$\frac{1}{305.5}$

Reviewing the tabular values, a most striking fact is found in the apparent close accord between the several results, thus testifying to the value of the measures; next we notice that the 5 arcs situated within the limits of the United States, when combined with the Peruvian arc, or among themselves, all demand a representative spheroid of somewhat larger dimensions than that of Bessel. This conclusion was already arrived at in 1877,‡ but was then based upon quite slender evidence as

*Coast Survey Report for 1877, Appendix No. 6. The Peruvian arc was measured between the years 1735 and 1743; its amplitude is $3^\circ\ 07'\cdot 1$. The Peruvian arc is referred to by members of the Coast and Geodetic Survey in the annual reports for 1877 (p. 95), for 1889 (p. 199 and foll., and again p. 494 and foll.) and for 1898 (Appendix No. 4).

†The Nantucket arc of meridian was measured between the years 1845 and 1866; the Pamlico-Chesapeake arc of meridian was measured between the years 1844 and 1876.

‡Coast Survey Report for 1877, p. 94.